INSTRUCTION MANUAL

D. C. AMPLIFIER

MODEL 64AA

Electro-Mechanical e·m·r Research, inc.

RIDGEFIELD, CONNECTICUT

SARASOTA, FLORIDA

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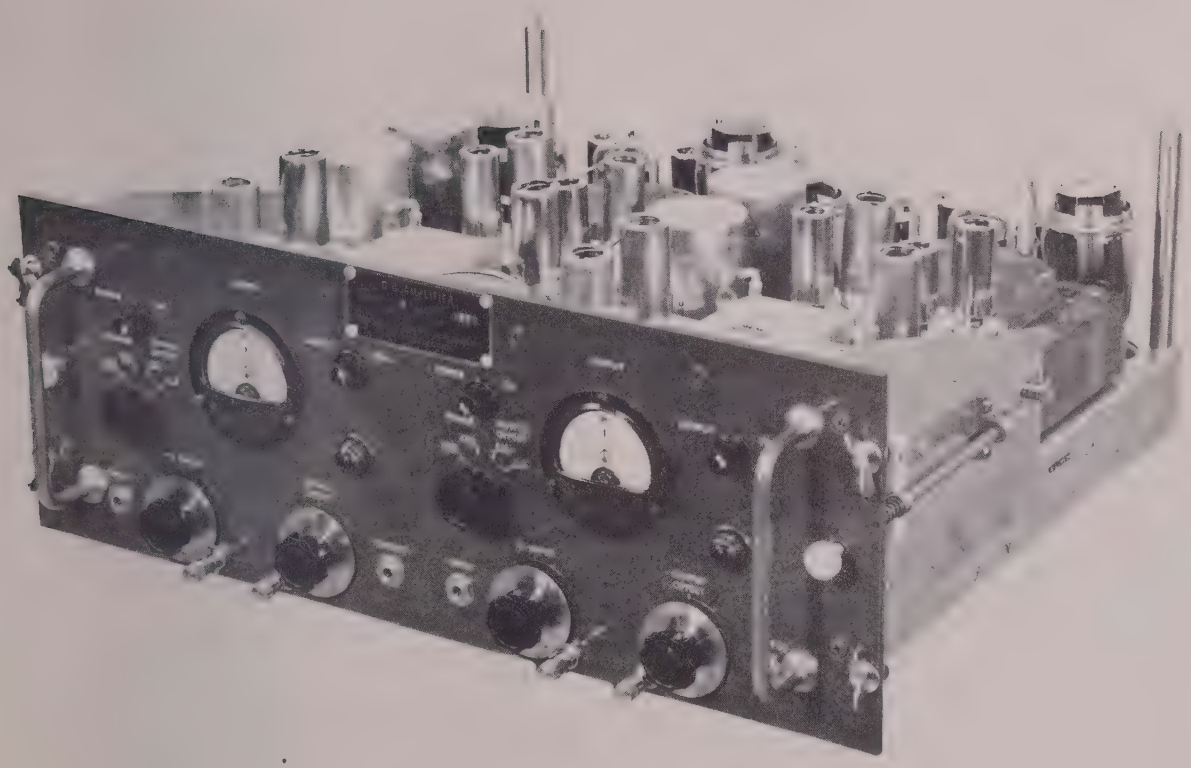
STABILIZED D.C. OUTPUT AMPLIFIER
MODEL 64



The Model 64 Chopper-Stabilized D. C. Amplifier is a general purpose instrument with a nominal linear pass band capability from DC to 10 Kc and a maximum gain of 100. The amplifier is intended for general laboratory and instrumentation use. Typical applications are the amplification of signals within the 1 to 10 volt range to an output level sufficient to drive pen motor recorders and high speed string galvanometers.

When the Model 64 Amplifier is used with recorders requiring frequency compensation, a plug-in equalizer network is utilized to achieve the desired compensation. This equalizer network determines the voltage gain, frequency response, output impedance, limiting, and source impedance.

SECTION III
DESCRIPTION, PERFORMANCE SPECIFICATION, AND INSTALLATION

1. GENERAL

The Model 64AA D. C. Amplifier is a dual channel general purpose instrument with a linear pass band capability from DC to 10 kc and a maximum gain of 100. It is intended for general laboratory and instrumentation use. Typical applications are the amplification of signals within the 1 to 10 volt range to an output level sufficient to drive pen motor recorders and high speed string galvanometers.

When the Model 64AA is used with recorders requiring frequency compensation a plug-in equalizer may be used to achieve the compensation desired.

The basic amplifier chassis consists of two identical amplifiers each being independent of the other and each having its own built-in power supply. Accessories include pull-out, turn-over slides, and Model 64A-5 ( ) plug-in equalizer units.

2. CHARACTERISTICS AND SPECIFICATIONS

PANEL SIZE:
Standard 7'' x 9''

CHASSIS SIZE:
16-1/8'' wide x 16-1/8'' deep x 1-7/8'' high.

WEIGHT:
70 lbs. maximum. (approximately 65 lbs.)

POWER SOURCE:
105 to 125 volts rms - 60 cps - 3.8 amps Maximum for two amplifier channels.

INPUT IMPEDANCE:
10,000 ohms shunted by approximately 100 mmf.

INPUT ATTENUATOR:
Calibrated potentiometer 10,000 ohms total.

TYPE OF INPUT:
Single ended.

INPUT RANGE:
±1 to ±10 volts peak.

FREQUENCY RESPONSE CAPABILITY:
Flat, DC to 10 Kc within ±1%. 3 db down at about 100 Kc. Other frequency response characteristics available with equalizer.

INTERMODULATION COMPONENTS:
Less than 1% of rated output, unless compensated equalizer is used.

NOISE:
Less than ±3 millivolts referred to the input.

VOLTAGE GAIN:
Up to 100 times depending upon equalizer used.

PHASE:
The output voltage is in phase with the input potential.

OUTPUT VOLTAGE:
Up to ±100 volts peak depending upon equalizer and load impedance used.

OUTPUT CURRENT:
Up to ±100 ma. peak depending upon equalizer and load impedance used.

LINEARITY:
Better than 0.1% of full rated output.

TYPE OF OUTPUT:
Single ended.

OUTPUT SOURCE IMPEDANCE:
Amplifier characteristic terminal impedance varies from less than 1.0 ohm to approximately 25 ohms maximum at DC to medium audio frequencies, depending upon the equalizer used. Higher output impedances may be obtained by inserting resistance elements in the equalizer plug-in unit.

PEN MOTOR CENTERING CONTROL:
No amplifier balance control is provided or required. However, an electrical centering control having an effect equivalent to ±1.3 volts DC input signal is provided for galvanometer centering and may be switched in or out of the amplifier circuit as required. The centering is continuously adjustable by a panel control and may be used when galvanometer mechanical aero-

sets are not easily accessible. The resulting output voltage offset registers on the output panel meter but the input terminal impedance or potential is in no way affected by this control since it operates in the DC feedback loop circuit.

GROUNDS:

Input and output are normally grounded. However, the entire circuit may be isolated from the chassis and the input may be connected across a balanced low impedance source. Capacitance from circuit to chassis under these conditions does not exceed 0.005 mfd.

EQUALIZATION:

A plug-in equalizer may be used to flatten and broaden the frequency response of pen-motors and strings.

3. EQUALIZER CHARACTERISTICS:

A. GENERAL

The Equalizer unit (64A-5) of the Model 64A Amplifier determines the performance of the amplifier within the overall capabilities of the amplifier. The three Equalizer types described below are representative of the units which can be supplied. Equalizers can be furnished providing: any gain from unity to over 100 times; a variety of load impedances; various meter scales; source impedance; limiter action; and frequency compensation.

> NOTE: The 64A Amplifier may be operated with any load impedance regardless of the Equalizer used. Full specified performance may not be obtained for load impedances less than those noted below.

B. MODEL 64A-5A EQUALIZER

This unit is designed for use with a Sanborn Recorder Model 127, or units with similar pen motor characteristics. The Equalizer is peaked 10 db at 120 cps to provide frequency compensation which permits a net amplifier plus recorder response which is nearly flat from DC to 60 cps and gives a good square wave response with minimum overshoot effect. Usable pen deflections may be obtained up to 100 cps. The other operating characteristics are listed below:

1. USE: With any 64A amplifier channel.
2. VOLTAGE GAIN: 100 times at DC and 10 cps; 300 times at 120 cps; attenuated thereafter.
3. FREQUENCY RESPONSE: Compensated for Sanborn Model 127 recorder and others having a similar pen motor.
4. LOAD IMPEDANCE CONNECTED TO 64A: 3000 ohms or greater.
5. MAXIMUM RATED AMPLIFIER OUTPUT VOLTAGE: Plus and minus 100 volts peak with ±150 volts peak available and usable.
6. MAXIMUM ±PEAK OVERLOAD VOLTAGE OUTPUT PERMITTED: Approximately ±150 volts peak.
7. 64A EFFECTIVE SOURCE IMPEDANCE: Approximately 25 ohms at DC
8. PANEL OUTPUT VOLT METER CALIBRATION: ±100 volts.

C. MODEL 64A-5B EQUALIZER

This unit has a voltage gain of 50 times with a flat frequency response from DC to 10 kc. It is primarily intended for use as a general purpose power amplifier and has many potential applications. The operating characteristics are listed below:

1. USE: General power amplifier.
2. VOLTAGE GAIN: 50 times.
3. FREQUENCY RESPONSE: Flat from DC to 10 kc. 3 db down at about 100 kc.
4. LOAD IMPEDANCE CONNECTED TO 64A: 1000 ohms or greater.
5. MAXIMUM RATED AMPLIFIER OUTPUT VOLTAGE: ±50 volts peak at 1000 ohms-load. Up to ±100 volts peak available for loads of 3000 ohms or greater.
6. MAXIMUM ± PEAK OVERLOAD VOLTAGE OUTPUT PERMITTED: Approximately ±110 volts peak.
7. 64A EFFECTIVE SOURCE IMPEDANCE: Approximately 15 ohms at moderate frequencies.
8. PANEL OUTPUT VOLTMETER CALIBRATION: ±100 volts.

D. MODEL 64A-5C EQUALIZER

This unit has a voltage gain of 100 times with a flat frequency response from DC to 10 Kc.

It is primarily intended for use as a general purpose power amplifier and has many potential applications. The operating characteristics are listed below:

1. USE: General power amplifier.

2. VOLTAGE GAIN: 100 times.

3. FREQUENCY RESPONSE: Flat from DC to 10 Kc. 3 db down at about 100 Kc.

4. LOAD IMPEDANCE CONNECTED TO 64A: 3000 ohms or greater.

5. MAXIMUM RATED AMPLIFIER OUTPUT VOLTAGE: ±100 volts peak to a 3000 ohm load. Up to ±150 volts peak available for somewhat increased load impedances.

6. MAXIMUM ± PEAK OVERLOAD VOLTAGE OUTPUT PERMITTED: Approximately ±150 volts peak.

7. 64A EFFECTIVE SOURCE IMPEDANCE: Approximately 25 ohms at moderate frequencies.

8. PANEL OUTPUT VOLTMETER CALIBRATION: ±100 volts.

E. MODEL 64A-5D EQUALIZER

This unit has a voltage gain of 1.0 times with a flat frequency response from DC to 10 Kc. It is primarily intended for use as a general purpose current amplifier and has many potential applications. The operating characteristics are listed below:

1. USE: General current amplifier.

2. VOLTAGE GAIN: 1.0 times.

3. FREQUENCY RESPONSE: Flat from DC to 10 Kc. 3 db down at about 500 Kc.

4. LOAD IMPEDANCE CONNECTED TO 64A: 50 ohms or greater.

5. MAXIMUM RATED AMPLIFIER OUTPUT VOLTAGE: ±5.0 volts peak to a 50 ohm load. Up to ±10 volts peak available for somewhat increased load impedances.

6. MAXIMUM ± PEAK OVERLOAD VOLTAGE OUTPUT PERMITTED: Approximately ±7.5 volts peak, at 50 ohms load.

7. 64A EFFECTIVE SOURCE IMPEDANCE: Approximately 1.0 ohms at moderate frequencies.

8. PANEL OUTPUT VOLTMETER CALIBRATION: ±5.0 volts.

4. INSTALLATION

The dual channel amplifier chassis may be rack or cabinet mounted with input, output and power connections for both channels being made through a Cannon mating receptacle. This receptacle, Cannon number DPD-32C2-33S-1L is normally supplied with the amplifier. The schematic diagram number 64A-Z1 illustrates how these connections are made.

CAUTION

When the amplifier is to be used with a single-ended ground-referenced signal source a jumper connection between the three binding posts located on the rear center of the chassis may be made. The center post is permanently connected to chassis ground, while the posts to the right and left of center are the common connections for the right and left hand channels, respectively.

If this Jumper is removed and the common or "B-" lead is no longer connected to chassis ground for either channel, care must be exercised in making input and output connections. The two rear chassis connector coaxial input terminals have shield connections bonded to the chassis ground due to the manner of manufacture. If shielded input leads are required, the tip or center lead is connected to the center conductor, but the shield must be connected to the corresponding common or "B-" lead pins shown on the schematic diagram Drawing Number 64A-Z1, and NOT to the chassis ground or outer conductor of the coaxial connector. If complete shielding is desired, "Triax" or triple coaxial lead may be used, the inner shield being "B-" or common and the outer shield being chassis ground. Output leads should be handled in the same manner if shielding is required, and the chassis ground should not be connected to the common or "B-" lead.

CAUTION

If the chassis ground is not bonded to the common amplifier lead, any input or output test leads used must consist of a two

wire circuit with the chassis ground connection having very low capacity to the "hot" tip lead at all points in the circuit. If this precaution is not observed, high frequency parasitic oscillations may occur. If shielded input or output test leads are required, a "triax" or triple coaxial cable may be used since in this case the "hot" tip lead is shielded by the "common" lead (sleeve) from the chassis ground outer shield connection. No special precaution is necessary if the chassis ground is connected to the common lead of the amplifier excepting that excessive capacity from the "hot" input lead to the "hot" output lead must be avoided since the input and output terminals are electrically in phase.

If pull-out turn-over slides are utilized for rack mounting the amplifier, the following installation procedure should be employed. The rack slides should be extended out toward the front of the rack, and the amplifier carefully placed on the slides. The pivot retainers should be unscrewed from the U-shaped receptacles on each slide. Insert the two pivot pins located on each side of the amplifier into the U-shaped receptacle on each slide. When the pivots are nearly into the slide, pull out the two indexing pins on the side of the amplifier, away from the front panel. When the amplifier pivots are fully engaged in the slide, the pivot retainers should be inserted over the pivots to hold them in place, and screwed down. To slide the amplifier into the rack, push in on the indexing pins on the sides of the amplifier panel.

CAUTION: COOLING NECESSARY

Each dual channel 64AA Chassis dissipates power in the order of 400 watts which can cause an appreciable temperature rise if adequate cooling is not provided. Forced air ventilation should be provided for any rack assembly involving several units. Some installations may require the use of directed air streams in the center sections of the chassis to avoid excessively hot pockets.

5. ACCESSORIES

The following accessories are available for use with the Model 64AA Amplifier:

1. Pull-out turn-over slides.

2. Plug-in equalizers to supply any desired frequency compensation. When ordering plug-in equalizers the following information should be supplied:

A. Serial number of 64AA Amplifier with which the equalizer is to be used, designating right or left hand channel.

B. Voltage Gain -- maximum anticipated requirement.

C. Frequency response.

D. 64A operating output load impedance.

E. Maximum ± peak signal voltage output required.

F. Maximum ± peak overload voltage output tolerable.

G. Desired 64A effective output source impedance.

H. Panel output meter calibration ± peak output volts for full scale deflection.

SECTION IV
AMPLIFIER OPERATING PROCEDURE

. GENERAL

The Model 64AA amplifier is intended to amplify signals in the 1 to 10 volt and DC to 10 Kc range. It may be used to drive galvanometers and pen motors, or to operate in servo or other instrumentation systems.

A plug-in equalizer unit is required to operate each amplifier channel. This equalizer unit determines the voltage gain, frequency response, output impedance, limiting, and source impedance. The equalizer unit plugs into an Amphenol receptacle in the top of the amplifier chassis. Power should be turned OFF before any plug-in units are removed from or inserted into the chassis to avoid momentary electrical shocks to the operator.

2. INPUT AND OUTPUT CONNECTIONS

Input and output signal connections and A. C. power connections are normally made through a Cannon plug located on the rear chassis skirt, however, input and output test jacks are supplied on the front panel for convenience.

A Cannon number DPD-32C2-33S-IL receptacle is required for connection to the rear chassis plug. The input and output connections to each amplifier may be single-ended, referenced to ground or balanced not referred to ground. If a ground-referenced input and output are desired, a jumper connection between the three binding posts located on the rear center of the chassis may be made. The center post is permanently connected to chassis ground, while the posts to the right and left of center are the common connections for the right and left hand channels, respectively.

A 1/8 ampere slow blow fuse in the amplifier output stage is intended for protection of recording devices which may be connected to the amplifier. A fuse of different rating may be substituted when desired. The amplifier itself does not require this fuse protection. It should be remembered that the amplifier output impedance will be increased by the value of the fuse DC resistance. This fuse is located on the front panel. The output meter will continue to indicate even though this fuse is blown.

3. POWER SOURCE

The 64AA amplifier operates from a 105 to 125 volt, 60 cps line. Each channel may be operated independently drawing 1.9 amps each or 3.8 amps maximum for both. A 2 ampere fuse on the front panel protects the primary of each power transformer. NO specially regulated power source is required.

4. POWER SWITCH

Each amplifier channel has its own power switch on the front panel. This switch is combined with the + and - offset switch. Power may be applied after the amplifier has been connected to a mating receptacle. The panel light indicates continuity of the power line circuit.

5. OUTPUT OFFSET

After the amplifier has been allowed to warm up the output offset switch may be rotated to either the + or - offset position if desired. The DC output potential may then be moved in the desired direction by means of the "output offset" potentiometer. The offset output potential will be indicated directly on the panel meter and any input signal will appear at the output terminal with the mean DC value changed accordingly. The output offset control and the panel meter provide a convenient means of checking the individual amplifier channels for proper operation.

> NOTE: A momentary surge in the amplifier output may occur when the output offset control is rotated. This condition is normal and is due to the fact that the output offset potential is introduced into the DC feedback loop and not into the AC loop.

No output offset will occur at the amplifier output terminal if the power switch is rotated to the "ON" position.

6. % INPUT CONTROL

This control is a linear potentiometer and may be used as an input signal attenuator. When this control is rotated from its extreme clockwise position attenuation of the input signal will occur.

7. INPUT TEST JACK

A jack on the front panel is connected directly across the rear chassis connector input terminals. It may be used to connect a WE type 309 plug to

the amplifier input; the tip being "hot", the ring the common lead and the sleeve the chassis ground connection.

CAUTION

If the chassis ground is not bonded to the common amplifier lead, any input or output test leads used must be a two wire circuit with the chassis ground connection having very low capacity to the "hot" tip lead at all points in the circuit. If this precaution is not observed, high frequency parasitic oscillations may occur. If shielded input or output test leads are required, a "triax" or triple coaxial cable may be used since in this case the "hot" tip lead is shielded by the "common" lead (sleeve) from the chassis ground outer shield connection. No special precaution is necessary if the chassis ground is connected to the common lead of the amplifier excepting that excessive capacity from the "hot" input lead to the "hot" output lead must be avoided since the input and output terminals are electrically in phase.

8. OUTPUT TEST JACK

The output test jack located on the front panel, is connected directly across the output terminals of the rear chassis connector and may be used to connect a WE No. 309 plug to the amplifier output. The tip is "hot", the ring common or "B-" and the sleeve chassis ground.

CAUTION

Care must be exercised when using shielded output test leads as noted above in paragraph 7 - Input Test Jack - Caution if the chassis ground is not connected to the "B-" or common lead of the amplifier channel.

9. OUTPUT OFFSET CONTROL BATTERY

A small 1.3 volt mercury cell is located just behind the front panel. If the Output Offset control action becomes weak, this cell may be replaced by a Mallory RM-12 battery.

10. OUTPUT METER

A calibrated panel meter on the front panel indicates DC output volts. An output current limiter restricts the output to a predetermined maximum, regardless of input overloads. The maximum current limiting level is determined by the equalizer unit and is usually held to 150% of the maximum rated output with the specified load.

SECTION V
THEORY OF OPERATION

1. GENERAL

The 64A DC Amplifier comprises an output Power Amplifier driven by the parallel combination of an AC signal amplifier and a DC Chopper Amplifier. Suitable power supplies, an input attenuator, and integral DC signal source for controlled output offset are also provided on the amplifier chassis.

Drawing No. 64AA-Z1 is a simplified functional schematic diagram of the unit as a whole. Amplifier input signals may be attenuated by R-1 if desired and are then split; the AC components (generally greater than 1 cps) being supplied through C-1 to the AC signal amplifier 64A-1, and the DC signals being transmitted by R-77 to the chopper which converts DC to 60 cps square waves for amplification by the 64A-2 and 64A-3 units. The 60 cps square wave signals containing the DC signal information are demodulated and reconverted to DC by V-15 and its associated components. R-25 plus C-39 constitute the cross-over network and are used to recombine the DC and AC signals. The composite information drives V-4 which is part of the power output stage.

2. POWER AMPLIFIER

Drawing No. 64AA-Z2 is a simplified functional schematic diagram of the output power amplifier. This arrangement provides maximum efficiency in converting power supply energy into output load power with a minimum circuit complexity and maximum gain. The operation is as follows:

If a positive going input signal appears at the input, V_4 will draw a large current (I_1) through the output load (R_1) causing the ungrounded (hot) output terminal to go negative. The current I_1 flowing in R_{55} produces a negative voltage between the grid and cathode of V-7; V-7 draws less current (I_2) and the result is a still more negative output signal.

If a large negative input signal is applied to the input, V-4 will be cut-off and the current approaches zero, producing practically no voltage drop across R-55. Hence, V-7 has essentially zero bias between its grid and cathode and V-7 draws a large current I_2. This current acts to drive the output terminal positive and since no I_1 current is flowing practically all the tube current of V-7 is delivered to the output load. The other limiting case where V-4 is driven to zero bias or positive results in a large current I_1 which cuts off V_7 due to the drop across R-55 and hence practically all the current of V-4 is delivered to the load to drive it negative.

It should be noted that the screen grid circuit shown in 64AA-Z1 does not permit screen grid currents or regulator tube currents to flow in either the output circuit or the R-55 circuit since this would reduce the net efficiency. When unimpeded by the limiter stage (V3), this power amplifier is capable of delivering about ±150 ma to low impedance loads, or about ±200 volts to loads in the order of 3000 ohms.

The voltage gain of the power amplifier alone is in the order of 40DB for very high load impedances. When the net load is 2000 ohms (3K external load plus internal loads) the gain is 28DB. The relatively large shunt capacity to B-line of power supply T-1, V-9, and C-26 is in parallel with the output terminals and this causes the amplifier voltage gain to fall off at frequencies in excess of 10 Kc with a 2 K net load, but this effect is minimized by the AC amplifier and feedback circuits.

Since pentode tubes are used, the power amplifier alone closely approaches a constant current source (at constant input voltage) for load impedances below 2000 ohms.

One thousand ohm resistors (R29 and R56) are used in series with each output tube plate to prevent excessive plate dissipation at high plate currents since the 6146 tubes used will draw large plate currents at rather low plate voltages.

3. AC SIGNAL AMPLIFIER

The AC Signal Amplifier with the exception of the 1.0 uf coupling capacitors, C_1, C_4, C_7, and C_{39} is contained in the 64A-1 plug-in unit as shown in schematic diagram 64A-Z1. When pins 10 and 16 are open (no controlled high frequency attenuation) the assembly has a gain in excess of 40DB from about 1 cps to 600 Kc, being about 48DB in the range of 10 cps to 1 Kc. The input cathode is returned to the negative feedback divider shown in Drawing No. 64AA-Z1. Controlled high frequency attenuation is provided when low gain equalizer units are used to connect pins 10

nd 16 to ground. This permits a net open loop mplifier response which falls off at a rate of bout 8DB per octave maximum prior to the fre- uency at which the open loop gain reaches about 10DB regardless of the equalizer gain chosen. t a gain of 100 times (flat) the net closed loop requency response is flat within ±1% from DC to 0 Kc; the square wave response is good for any requency from DC to about 5 Kc with rather mall overshoot or ringing effects, and the 6DB own point for sine waves is in excess of 100 Kc.

The first stage of V1 is essentially flat to 00 Kc with about 18 DB gain. Stage 2 of V-1 has bout 6DB gain in the low frequency region but ises to around 18DB in the region of 100 Kc to 00 Kc. This provides a needed boost in gain at igher frequencies. The cathode topped grid eak (R8) permits a rather low frequency 6DB oint which improves stability in the crossover egion of 1 cps.

V2 is the final AC Amplifier stage and cath- de follower. The first section provides 20DB ain to nearly 1 MC when working into a cathode ollower load. The cathode follower permits ood high frequency response in V2 and provides low impedance source for AC signals driving he crossover network C39 and R25. This is es- ential since R25 presents an impedance to C39 nd the AC amplifier approximating 100 K divided y the chopper amplifier open loop gain.

. CHOPPER AMPLIFIER

Drawing No. 64AA-Z1 shows the interconection of the input signal, 60 cps chopper amlifier stages 64A-2 and 64A-3, and the demoduator circuit (V-15) which provides the DC inelligence signal to drive a crossover resistor 25 and thence the power amplifier. Details of he two plug-in unit assemblies 64A-2 and 64A-3 re shown on drawing 64A-Z1.

DC input signals delivered via R77 to the hopper are cut down to some different potential he feedback network) by the Brown Converter t a 60 cps rate, thus producing 60 cps square ave signals at the input to the 64A-2 amplifier nit on Pin 6. The net gain of this 2 stage amlifier is about 50 db as read between pins 6 & 9 hich are input and output respectively. Necesary high frequency attenuation is inserted by 34 to provide stability.

The gain of V14 in the 64A-3 unit is in the rder of 40 db when tested as a 60 cps amplifier ith V15 and R25 disconnected. However, the rime measure of importance is the conversion ain, ie, 60 cps input voltage to DC output voltage hange when using V15. If the RMS input signal change is in the order of 0.25 volts the DC output change will be about 10 volts DC, or a ratio of about 30 db (ignoring peak factors). The combined chopper amplifier conversion gain (64A-2 plus 64A-3) is 70 to 80 db.

In addition to functioning as a demodulator V-15 and its associated components supply a part of the negative bias required by the grid V-4. Due to the unbalanced arrangement of R90, R91, R92, R93, R94, and R95, the output of V15 will be a negative potential in the order of 20 volts when no signal is delivered to the plate of V-14.

NOTE: When the 64A is operating normally with feedback, the square waves observed in the chopper amplifier are much reduced in level and badly distorted by noise which is injected by the chopper drive coil, due largely to the high A_{DC} B_{DC} product used, however good performance results in spite of this noise. Chopper square waves appear distinctly and clearly when the 64A amplifier is producing plus 100 volts output into the rated load with normal feedback operation.

5. POWER SUPPLIES

A. GENERAL

The interconnection of the various amplifier power supplies is shown in block form on 64AA-Z1. Drawing 64A-Z1 gives the full details, and Drawing 64AA-Z3 is a functional drawing of the regulated power supply which comprise V-10 as a series valve tube and the 64A-4 plug-in unit as a combined voltage amplifier and reference voltage assembly.

B. HIGH VOLTAGE SUPPLIES

T-1, V-6, and C-16 comprise a high voltage rectifier circuit with the negative side tied to B- (input and output common lead), however, T-1, V-9, and C-26 comprise a separate high voltage rectifier circuit with the negative side returned to the "Hot" output terminal through R-55 as shown in functional form on Drawing 64AA-Z2 and Drawing 64AA-Z1. Special precautions have been taken to keep stray capacities under control and the power transformer includes rather extensive electrostatic shielding since excessive capacitive feedback from this "hot" supply circuit to the input via stray leads, the power lines, or the chassis (when it is floating) can cause parasitic oscillations at a high frequency.

C. REGULATED SUPPLY; +200 VOLT

The V-6, C-16 high voltage supply (referenced to B-) supplies power both to the output stage and the regulated supply. The regulated supply is conventional in form, but includes several special features for simplicity and good regulation. The series valve tube V-10 is connected conventionally and uses anti-parasitic resistors R65 and R66 to insure stability.

V-12 is a high stability type voltage reference tube effectively grounding the input cathode of V-11 which is the error amplifying tube. C-29 and R-67 stabilize the reference tube potential. Error signals are fed to the input grid from the regulated output via C-28 and voltage divider R-68, R-69, and R-70. The plate current of the input tube is supplied by R-71 so that this stage will have sufficient GM to efficiently drive the second half of V-11 which is connected as a grounded grid amplifier stage. This grid is pegged at a suitable DC potential by R-73 and R-74. The plate load is R64 plus R63 connected to the high voltage source for adequate plate current at high error signal levels. 120 cps noise is reduced by the filter effect of R63 and C27.

The regulator system described above will reduce the power supply ripple by the amplifier open loop gain factor, but it cannot reduce the ripple to zero. A balanced bridge effect is added which is capable of producing nearly zero ripple output at one discrete set of conditions. This bridge circuit includes R59, R60, C25, R99 and R57 which injects power line noise into grid 7 of V-11 at such a phase as to cancel ripple voltages appearing on the regulated output line. C-68 and R-59 are used for phase correction to compensate for the effect of C-27 and others.

The 120 cps saw tooth ripple appearing at C-16 is in the order of 75 volts P-P (25 volts RMS). Without the bridge circuit, the 200V regulated line ripple is in the order of 40MV P-P (14 MV RMS) which implies a regulated supply net gain of 60 to 70 db. With the bridge circuit connected a net regulated supply ripple voltage in the range of 1 to 2 MV RMS is obtained, which indicates that a reduction of about 20 db is obtained from the bridge circuit.

NOTE: R76 pegs the heater line Y-1, Y-2 at about 86 volts, and C-30 by-passes this point to B-. If C-30 and R-76 should connect to different heater leads instead of a single common point (Y-2) severe 60 cps regulated power supply noise will result.

6. FEEDBACK CIRCUIT, OUTPUT OFFSET, AND EQUALIZER UNIT

A. GENERAL

The 64A Amplifier is accurate and stable primarily because of the feedback loops employed around all tubes and including the chopper. The three primary feedback circuits are shown in functional form on Drawing 64AA-Z1. The circuit details are contained in Drawings 64A-Z1 and 64A-5C. These notes apply particularly to a gain of 100 equalizer for operation from DC to 10 Kc (64A-5C) but are generally applicable to any equalizer unit with any gain from unity to somewhat over 100 times.

B. AC AND DC FEEDBACK

Drawing 64AA-Z1 shows that 1% of the output potential is returned to the input AC Amplifier cathode providing negative feedback around the complete AC Amplifier. In a similar way, 1% of the output is returned to the chopper arm. When the output offset potential is shorted out (the "ON" position for SW-1 and SW-12 which are ganged) the input signal (DC component especially) is chopped to this feedback level. Hence, the 70 cps chopper amplifier sees only the "error" or difference between the input signal and 1% of the output signal. This error signal can be either positive or negative depending on whether the input potential is greater or less than that of the output. Hence, the DC Chopper Amplifier acts like any common feedback amplifier, ie, it operates only on error signals and its gain is very nearly the reciprocal of the feedback factor B (B_{DC} being 1%).

C. CHOPPER INTERMODULATION EFFECTS

If a 59.8 cps signal is delivered to the input it will appear in routine manner in the AC amplifier but will also be present in the input to the chopper amplifier. When the chopper is open, the grid cathode potential on the V-13 input stage will be the full input level, not a small error signal. Such a signal would overload the chopper amplifier which is sensitive to small error signals and would be mixed with 60 cps in two nonlinear elements; ie, the chopper and the demodulator tube V-15. The result would be severe distortion plus large sum and difference frequencies. The AC Amplifier feedback loop will greatly reduce the sum component but cannot do much about the 0.2 cps difference frequency which is below its pass band.

To avoid these intermodulation effects between the chopper and signals near the 60 cps

chopper frequency the input cathode of V-13 is also returned to a feedback divider at about 1% of the output voltage. If this ratio is carefully adjusted the grid-cathode voltage when the chopper is open will be very nearly zero for frequencies near 60 cps. Similarly, when the chopper is closed, the chopper arm and V-13 cathode are at very nearly the same potential and hence no appreciable grid cathode potential exists.

For a condition where no potential exists between grid and cathode of a tube, the plate voltage will be nearly constant. In this manner, input signals in the order of 60 cps are balanced out of the chopper amplifier and hence the intermodulation component may be reduced to well below the 1% allowable.

D. OUTPUT OFFSET

It has been noted that the chopper amplifier operates on the DC error signal between input and output. If a small battery potential is inserted for output offset as shown in Drawing 64AA-Z1, this will appear to the chopper as an error signal and the DC circuit will rebalance at a new output level. Thus, a small battery (Mallory RM-12) in the Chopper arm return circuit has the same effect as a DC input signal (with reversed polarity due to the reciprocal action of feedback), however the battery need not be physically in the input circuit and hence does not in any way affect the equipment connected to the input terminals. When the output offset potential is inserted quickly it will affect the amplifier momentarily in an erratic manner, since the circuit change has been introduced in only one feedback path of the 3 necessary for overall stability.

This does not present a problem since there is no need to vary the output offset rapidly when centering galvanometers, etc. Whenever the output offset control is used (SW-1 and 2 plus R-34) the output voltmeter will indicate its effect.

E. DETAILED FEEDBACK DISCUSSION

As will be noted on the equalizer drawings 64A-5 A, B & C; the feedback network is somewhat more involved than indicated above. The three dividers have one common element R45 and then branch out into 3 independent dividers.

Three independent dividers are essential for several reasons. First, any current flowing from the cathode of V-1 into the chopper arm will produce an offset just like a battery. Secondly, the B settings of the 3 legs are not exactly equal but are adjusted for equal net gains at the amplifier output terminals. As mentioned above, the AC gain, exclusive of the power Amplifier is about 48 db; the DC gain is about 75 db and the Power Amplifier gain is around 28 db for a 3000 ohm load. Hence, the open loop DC gain (A_{DC}) is near 100 db, but the AC open loop gain (A_{AC}) is only 75 db. Since the closed loop gains (A^1) be identical, the B's must differ.

Terman gives: $A^1 = \frac{A}{1-AB}$

Hence $$\frac{A_{DC}}{1-A_{DC}B_{DC}} = \frac{A_{AC}}{1-A_{AC}B_{AC}}$$

$$\frac{10^5}{1-(10^5\ B_{DC})} = \frac{5.6 \times 10^3}{1-(5.6 \times 10^3\ B_{AC})}$$

which becomes

$$B_{AC} = B_{DC} \pm 1.7 \times 10^{-4}$$

If B_{DC} is assigned as 0.01000

$$B_{AC} = .01017$$

or B_{AC} exceeds B_{DC} by 1.7% at a closed loop gain of 100 times as the closed loop gain decreases this difference becomes insignificant.

The input cathode of the 60 cps chopper amplifier cannot be tied to the chopper arm or DC offset will result. If it is pegged to the AC Amplifier, however, the ratio will be off about 1.7%. Hence, a third divider is necessary for this circuit.

F. ZERO BALANCE USING FEEDBACK

Drawing 64A-5C shows three divider resistors coupling some current from the negative side of the V-9, C-26 power supply into the feedback lines. This current from a point always more negative than the output terminal flowing in the DC chopper feedback circuit acts to center the amplifier output at 0.0 volts.

Referring to Drawing 64AA-Z2, it can be seen that if no bias is supplied to the V_4 power amplifier grid, the amplifier will produce a large negative output signal at zero input. This is prevented by three methods: First, feedback reduces the inherent offset of about 200 volts by the A_{DC} B_{DC} factor which is $10^5(10^{-2}) = 10^3$, ie, the offset is reduced to about -200 millivolts. Secondly, V-15 and its components supply an effective negative bias, but this cannot be used exclusively or

the unit will be excessively sensitive to power line voltage changes since this bias is directly proportional to the line voltage. Third, the feedback current from the negative side of C-26 (via R-40) is an effective negative potential in the DC chopper return circuit producing a positive going offset. Since this point varies directly with output current, feedback must be applied in equal ratios to all 3 points (via R-37, 40, and 43). This method cannot be used exclusively since the output feedback line is then referenced not to the output terminal but to a point 250 ohms (R55) distant, and unsatisfactory performance may occur.

G. OTHER EQUALIZER FUNCTIONS

Small capacitors (C_{20}, 21, and 22) are provided to stabilize the amplifier very high frequencies and compensate for inductive effects in wire wound resistors.

The output voltage meter multiplier resistor (R49) is included in the equalizer so that scales may be changed to suit various gains and output levels.

Two of the four output voltage limiting tube bias resistors (R47 and R48) are included in the equalizer so that the maximum excursion of the power output amplifier tubes may be controlled in the equalizer unit.

H. SPECIAL FREQUENCY COMPENSATION

Some equalizer units are not designed to provide flat frequency response from DC to 10 Kc, but are peaked and/or attenuated in a special form to provide compensation for a particular recorder frequency response. For example, the 64A-5A Equalizer is adjusted to give 10 db more gain at 120 cps than at DC, and to fall off rather rapidly thereafter. This response curve was carefully chosen to give the best performance of a Sanborn Recorder with flat frequency response and good (minimum overshoot) square wave response. The limiter biases were set to protect the Sanborn Pen Motor from serious damage on momentary overload while providing the maximum safe square wave deviation amplitude.

The frequency response peaking effect is controlled by C-19 and R-46 in the 64A-5A unit. C-19 plus R-46 attenuate the feedback (B is decreased) at 120 cps and beyond L_1 plus C-20, 21, and 22 increase B to a rather large value at high frequencies; approaching unity at about 100 Kc. Since the A_{AC} B_{AC} product at 120 cps is 10 db less than a flat unit (ie, 64A-5C) the 120 cps noise may be as much as 3 times greater than a flat unit.

7. OUTPUT POTENTIAL LIMITER

The action of the output limiter V-3 is outlined in drawing 64AA-Z1 in functional form. This limiter will protect the load from excessive voltage if the load resistance is specified. If the load resistance is not specified the limiter will operate on a combination of peak voltage and peak current effects since it acts to restrain the power output tube grids at a predetermined level, and the power output stage somewhat resembles a constant current source at low load impedances.

The simplest form of limiter is on the grid of V-7. If the applicable cathode of V-3 is held at some positive voltage the grid cannot be driven above this potential due to the high impedance of R-53 and the low impedance of V-3 and R-48 plus R-51. Since the V-7 stage resembles a cathode follower connected to the load (for limiter purposes only) it will not drive the load appreciably more positive than the bias setting on the cathode of V-3. Since V-4 cannot drive the output positive, V-7 governs and positive going limiting is obtained.

Negative going limiting is provided by clamping the grid of V-4 using the other half of diode V-3. V-4 supplies increasing negative going outputs when its grid is driven more positive, but it is always negative with respect to ground. The desired negative reference potential is available on the output line at this instant and a divider (R27 and R47) is used to set the level as desired at minus 150 volts output, the appropriate cathode of V-3 will be about minus 15 volts, hence the grid of V-4 cannot go more positive than this level. Negative going limiting is thus obtained since V-4 governs and V-7 cannot supply negative output signals.

The 64A Amplifier will operate satisfactorily in the absence of this stage (V-3) and the tube may be removed. At this time, larger output signals may be obtained, but the load is unprotected. The 64A Amplifier itself does not require the protection of V-3.

8. NOISE REJECTION

A. GENERAL

Reference to Drawing 64AA-Z1 and Drawing 64A-Z1 indicates that although the low level signal amplifiers are supplied by a well regulated line the power output stage is driven from a simple rectifier and capacitor circuit containing about 26 volts RMS ripple at 120 cps. The

ripple tolerable at the output terminals is 300 millivolts RMS maximum and most units may be expected to produce less than 100 millivolts RMS at a gain of 100 times. This 120 cps ripple reduction is obtained in several ways as listed below:

B. AC AMPLIFIER

Primarily, the ripple reduction is accomplished by the AC signal amplifier and the feedback circuit. Any ripple which would be present in the output in the absence of feedback will be reduced by the feedback factor A_{AC} B_{AC} which is (5.6×10^{3}) (10^{-2}) or 56 times.

C. POWER AMPLIFIER

Secondly, the power amplifier is designed to produce as little ripple as feasible without feedback. The screen regulator tubes (V-5 and V-8) reduce the screen grid noise considerably. Pentode tubes tend to have a plate current which is relatively independent of plate voltage, thus attenuating ripple currents. At balance the ripple currents tend to cancel, but away from zero output, one tube will contribute ripple currents not counteracted by the other.

D. BRIDGE NOISE REJECTION

Third, the remaining 120 cps ripple components are reduced by a quasi bridge circuit which injects controlled 120 cps signals into the AC Signal Amplifier in such phase as to cancel most of the remaining 120 cps noise. This circuit comprises R22, R23, R97 and R10 shown on 64A-Z1. The adjustment procedure calls for varying R-23 for minimum 120 cps noise when the output potential is adjusted to minus 100 volts (using the output offset control). The output is then moved to plus 100 volts and R-101 adjusted for minimum 120 cps noise. These adjustments are then rechecked at the output extremes and zero output. This circuit and procedure takes into account the varying contributions of V-4 and V-7 to the output noise as the output voltage changed.

Sixty cycle noise components will also be observed. These may be contributed by an unbalanced rectifier tube, chopper demodulation components, and power transformer stray capacities to B- and chassis and input when the B- line is not connected to chassis.

Rectifier unbalance effects are reduced by installing a new rectifier. Chopper demodulator effects are diminished by C-39 which injects a small chopper signal into the AC Amplifier in such phase as to oppose these effects, and by C-12 and C-13 which inject 60 cps power signals into the AC Amplifier in such phase as to oppose the demodulator bias supply 60 cps component. The effect of stray capacities when the B- line is not grounded to chassis are minimized by C-17.

SECTION VI
MAINTENANCE

1. INSPECTION

The Model 64A DC Amplifier should be given a regular inspection similar to that recommended for other types of electronic equipment. A visual inspection should be made each month or oftener if experience dictates, checking for loose components and evidence of overheating. A complete inspection every six months should include the following:

a. Testing all vacuum tubes, batteries and chopper.
b. Tightening all screws and locking bars.
c. Inspect wiring for loose connections and evidence of overheating.
d. Checking all connectors for good contact efficiency.
e. Checking all tube socket and test point voltages (See Tables I and IA)
f. Checking performance (See below)
g. Replacing defective components (See Electrical Parts List Table II)

2. COOLING

Blower fans and air filters associated with this equipment should be regularly inspected and maintained in such condition as to provide adequate cooling. If signs of severe overheating are observed additional cooling equipment should be installed. Special care may be required to avoid hot air pockets in the center portions of the amplifier.

SECTION VII
PERFORMANCE TESTS

1. GENERAL

The 64A DC Amplifier may be given performance tests by referring to Section III, which gives the description and installation, plus operating characteristics and performance specification for this amplifier. The user should also be familiar with the OPERATING PROCEDURE given in SECTION IV. In addition, reference should be made to the inspection record supplied by EMR with each amplifier and each equalizer. More detailed tests may be conducted after the inspector has become familiar with the Theory of Operation given in Section V. Special procedures which may be of assistance in testing this particular type of amplifier are noted below.

2. PRELIMINARY TESTS

Tests to determine whether the amplifier is operating can be made using the output offset controls and front panel output voltmeter. Operation of these controls will insert an equivalent input voltage of zero, or plus or minus 1.36 volts. The output voltmeter should deflect in direct proportion, being zero at zero input and gain times output offset at other inputs. For example, a gain of 100 equalizer unit will produce a meter deflection of full scale (100 volts) when an offset of 1 volt (about 2/3 full clockwise rotation of the output offset potentiometer) is supplied. Polarity labels should be observed.

3. INPUT-OUTPUT MEASUREMENTS

A. CONNECTIONS

An audio oscillator covering the range 5 cps to 600 Kc, a battery (1.5 or 6.0 volts), and an oscilloscope may be used to make nearly all required measurements. Input signals may be connected to the rear chassis connector (see 64A-Z1) or the input test jack. The test jacks are connected for "Hot" Tip, B- on Ring and chassis ground on sleeve. Ring and sleeve may be shorted by the rear chassis binding posts. Output signals may be obtained from the rear chassis connector or the panel output test jack. Suitable load impedances (equal to or greater than those specified for the equalizer in use) should be connected to the input.

B. DC AND LOW FREQUENCY MEASUREMENTS

The battery input signal will produce output voltages measureable with the panel output meter and oscilloscope connected to the output terminals. Keying this battery signal at about 5 cps will generate square wave input signals which will be reproduced on the scope (set for DC gain) with good accuracy provided a flat equalizer is used and overload is not encountered.

Special compensated equalizers will produce an overshoot on the leading edge of square waves having a ratio of about 3:1, and the rise time will be depreciated. This overshoot peak must not strike the limiter threshold or clipping will result.

C. LIMITER MEASUREMENT

Limiter action may be observed by overdriving the input and observing the maximum voltage excursion passed by the amplifier. This will be about ±150 volts for X100 equalizers and about ±100 volts for X50 equalizers. This test may be conducted with any signal source at any frequency since the limiter is practically insensitive to frequency. Gain and frequency response may be checked by observing the relative input and output level of the amplifier at a variety of frequencies. Test equipment should be verified by conducting a similar test with the scope connected directly across the audio oscillator.

D. INTERMODULATION TESTS

Intermodulation effects may be observed by driving the amplifier at 30, 60, 120 and 180 cps (and near vicinity) and using a slow sweep speed on the scope which is set for DC gain. The crest of the signal wave will show the linear addition of the signal frequency and the difference component between the line frequency or its harmonic and the signal frequency. This crest should have a total amplitude less than 1% of the total output level provided overload is not encountered and noise levels are negligible.

E. ZERO INPUT ERROR TESTS

Noise, drift and zero offset may be observed by removing the input signal and observ-

ing the output with the scope set for DC. Scope zero may be checked by removing the output fuse (F_2) and shorting the scope input.

F. LINEARITY MEASUREMENT

DC linearity is difficult to observe without precision decade boxes or a bridge null detection system. If a gain of 100 equalizer is used, the output voltage across a 3K load may be observed and compared with a ±100 volt input signal (attenuated to ±1 V by the input pot and external dividers) using a null detector. Balance must be obtained at one output voltage other than zero (it is usually best to use minus 100 volts) at the same null setting as observed at zero input. This removes the effect of output offset errors. The input is then varied over the ±100 volt range and null errors noted. Since 0.1% of 100 volts is 0.1 volt, a vacuum tube voltmeter will suffice for a null detector if case grounds are considered. The null should remain within ±100 MV over the range of ±100 volts.

Distortion of AC signals may be observed using a wave analyzer and good quality audio oscillator. Since the distortion of the 64A is only a few tenths of 1% the audio oscillator employed must be better than this. Good quality low pass or band pass filters (such as those used in telemetering equipment, ie, subcarrier discriminators) when properly used should attenuate the harmonic distortion components of the audio oscillator to a negligible amount.

G. OUTPUT IMPEDANCE MEASUREMENT

Output impedance measurements may be made by driving the output load resistor low side through an audio oscillator and noting the relative voltage readings of the driver and amplifier output terminals.

This ratio is then applied to the load resistance used and provides a measure of the output impedance of the unit. The 1/8 Amp. (F-2) output fuse should be temporarily shorted or replaced by a 2A fuse (such as F-1), since the resistance of this fuse is comparable to the amplifier impedance.

SECTION VIII
TROUBLE SHOOTING PROCEDURES

. GENERAL

Trouble shooting the 64A DC Amplifier will e much simplified if the operator is thoroughly amiliar with all the preceding sections of this anual. The Maintenance (Section VI) outline hould be followed carefully before other trouble hooting procedures are undertaken; especially he parts concerning tube testing, inspection for ose connections (or poor sockets or connectors), nd signs of overheating (burned wires or com- onents). The inspection record supplied by EMR or each amplifier and each equalizer may be of ssistance.

The equalizer unit to be used in conducting he following tests should preferably be a "flat" nit with a gain of 50 or 100 times, since com- ensated units may give misleading effects in ase of trouble. Frequent reference will be made o Drawing 64A-Z1.

2. PRELIMINARY

The preliminary tests of Section VII, Part 2 should be performed and if this test gives a nega- ive result routine measures outlined above should disclose a remedy.

3. POWER AMPLIFIER CONTROL

A battery and low impedance potentiometer should be connected to the input of the output power amplifier and this stage tested separately. As inferred in Section V (Theory of Operation), a potential of about -25 volts at the junction of R26 and R28 (referenced to B-) will produce an output near zero volts DC. V-3 should be re- moved temporarily. Varying this battery power- ed input should drive the power amplifier to well beyond ±100 volts. If so, the trouble is not in the power amplifier, and the unit may be operated with the power amplifier pegged at zero output and controlled by this artificial signal while tests are conducted on other sections. At this point, a 2 Amp. fuse should be inserted in F-2 and the output shorted to B- to remove feedback from other stages.

Power supply voltages and ripples should be checked, along with tube element potentials.

4. AC AMPLIFIER

Section V should be consulted for power sup- ply troubles. The AC Amplifier may be driven by a low level audio signal through the input and its performance checked in the absence of feed- back on a stage by stage basis. Externally mounted C-1, C-4, C-7, and C-39 provide con- venient interstage check points. The 64A output terminals should be shorted for this test or ex- traneous signals will be observed.

5. DC AMPLIFIER

The DC Amplifier may be checked similarly. The chopper output at 6 on 64A-2 will be a square wave having a magnitude and phase controlled by both the DC input signal amplitude and polarity, and the output offset battery injection amplitude and polarity. Unless overload and noise effects are present the same square wave will be ob- served (with same rise time depreciation) throughout the 64A-2 and 64A-3 units. Section V (Theory) should be consulted for details and fur- ther test notes on the chopper amplifier.

> NOTE: When the 64A is operating norm- ally with feedback the square waves ob- served in the chopper amplifier are greatly reduced in level and badly dis- torted by noise which is injected by the chopper drive coil, due largely to the high A_{DC} B_{DC} product used, however good performance results in spite of this noise. Chopper square waves appear most distinctly and clearly when the 64A Amplifier is producing plus 100 volts output into the rated load with normal feedback operation.

6. FEEDBACK RATIOS

The Amplifier may be turned off and the out- put shorting leads removed. If the output ter- minals are driven by a 10 volt RMS signal, 1% (or 2% - depending on the equalizer B ratio) of this signal (at any frequency) should be observed on the following 3 points:

a. Pin 4 - 64A-1 unit (AC cathode and AC gain)
b. Pin 4 and 5 of the Brown Chopper (DC gain)
c. Pin 8 of 64A-2 (60 cps amp. cathode - Intermodulation)

4

As noted in the theory section, failure to obain the current B ratio in any one of these points ·ill produce erratic amplifier performance.

'. LIMITER ACTION

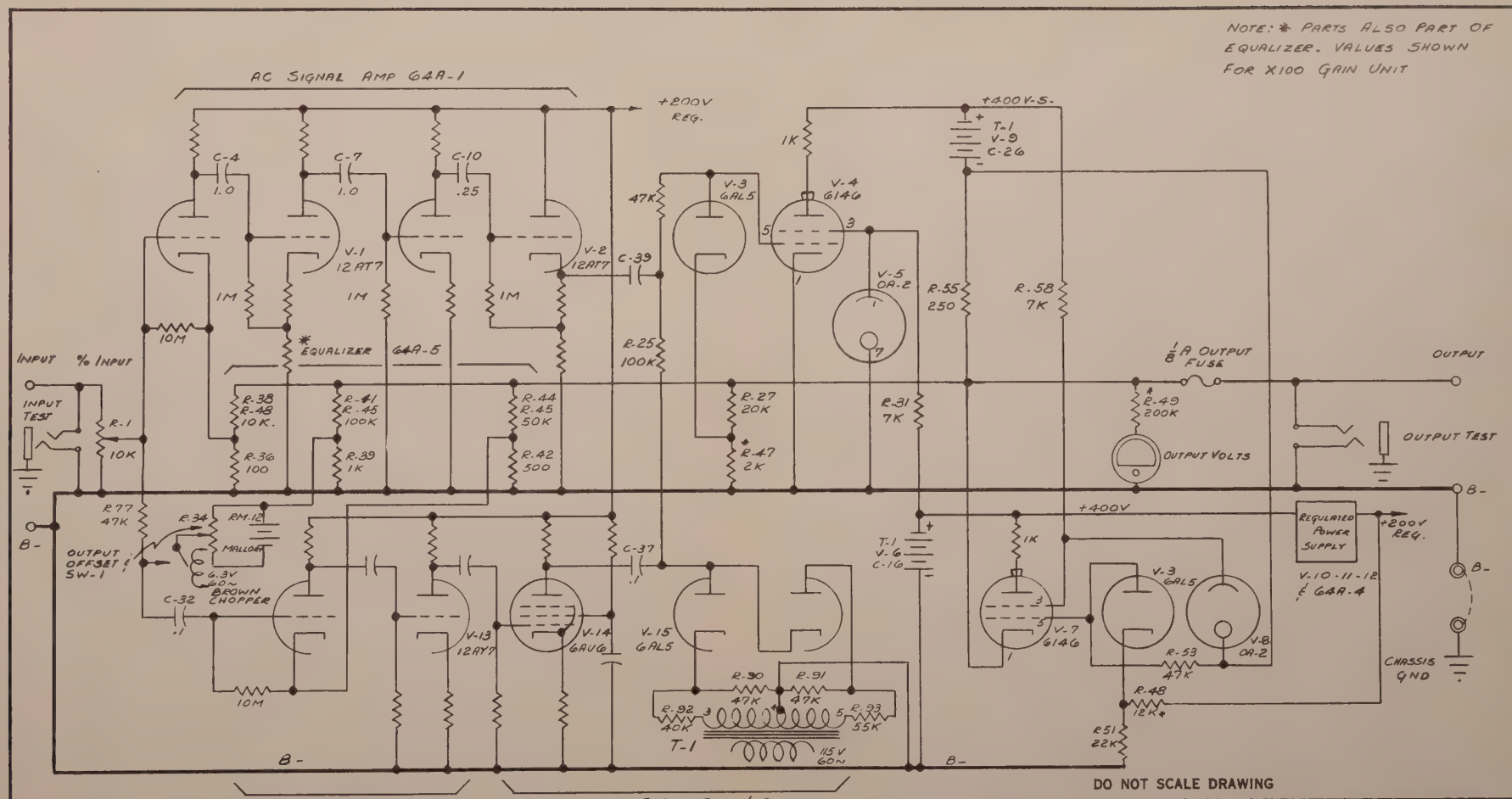
If the limiter stage (V-3) is found to be the nly fault its bias ratios (outlined in Section V) nay be checked. If desired, the 64A Amplifier ·ill operate without this tube except that larger utputs are available in the presence of greater nputs and the load is not protected.

8. GROUNDS

Short circuits to chassis which are difficult to find may be more easily located if the B- to chassis jumper is removed at the rear chassis binding posts, and also removed from all connecting lead. Ohmmeter checks should help locate any short circuit or leakage to chassis. If no short or leakage exists, the B- to chassis resistance should exceed 100 megohms and the capacity should be less than 5000 mmf.

SECTION IX

TABLES AND DRAWINGS



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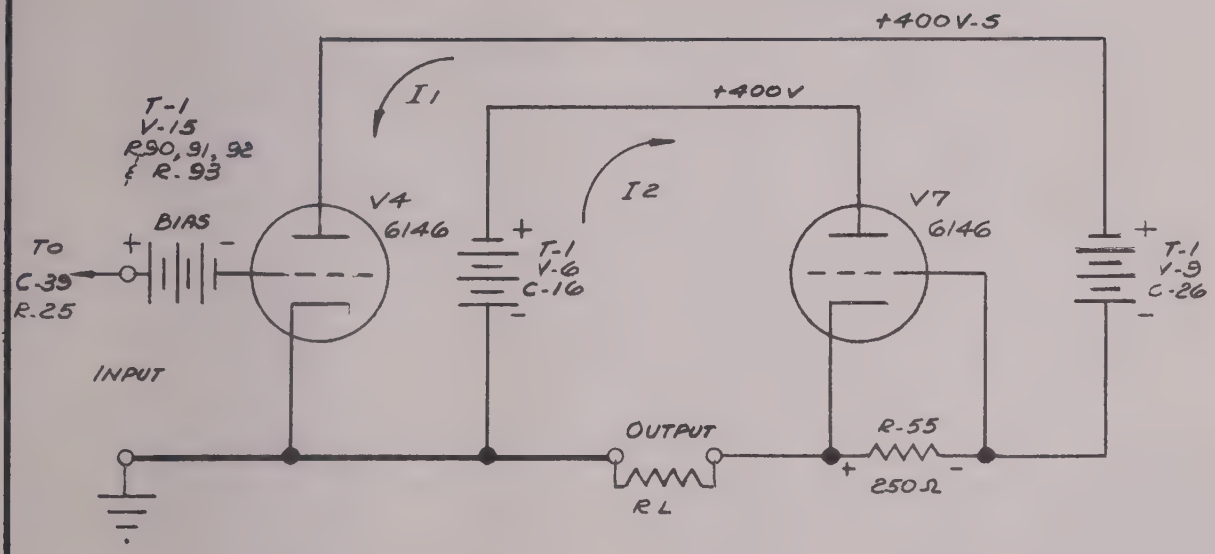
					64AA-21

B-00149



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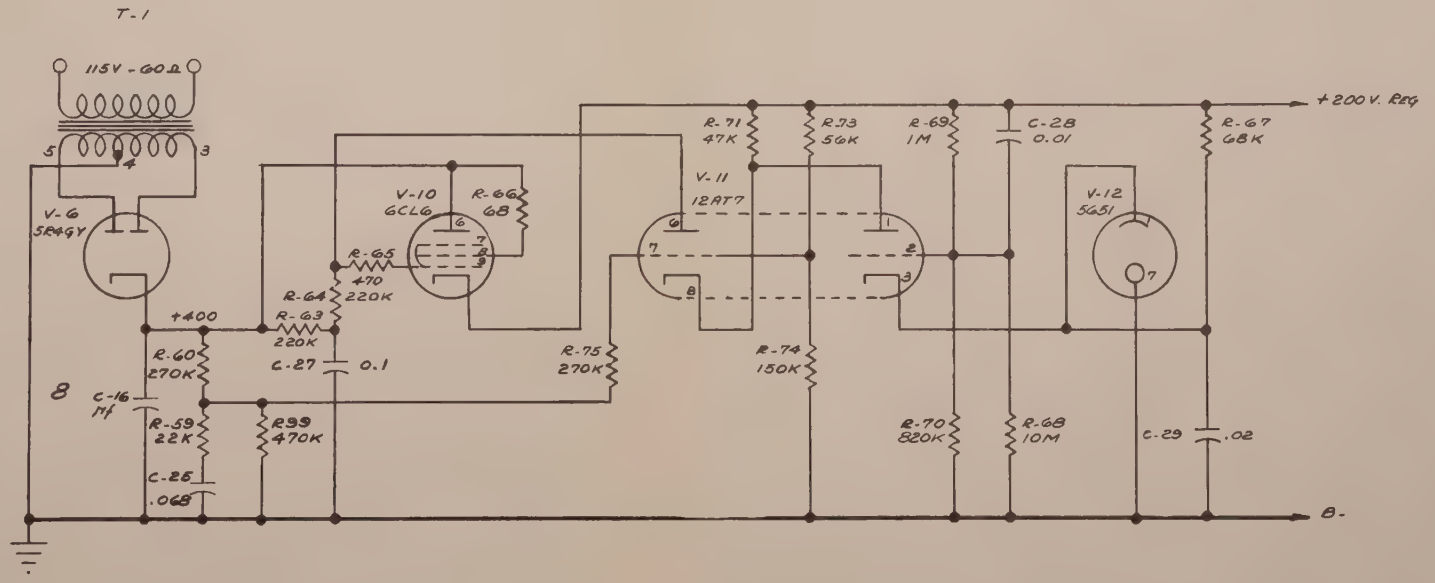

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DECIMAL ± .005

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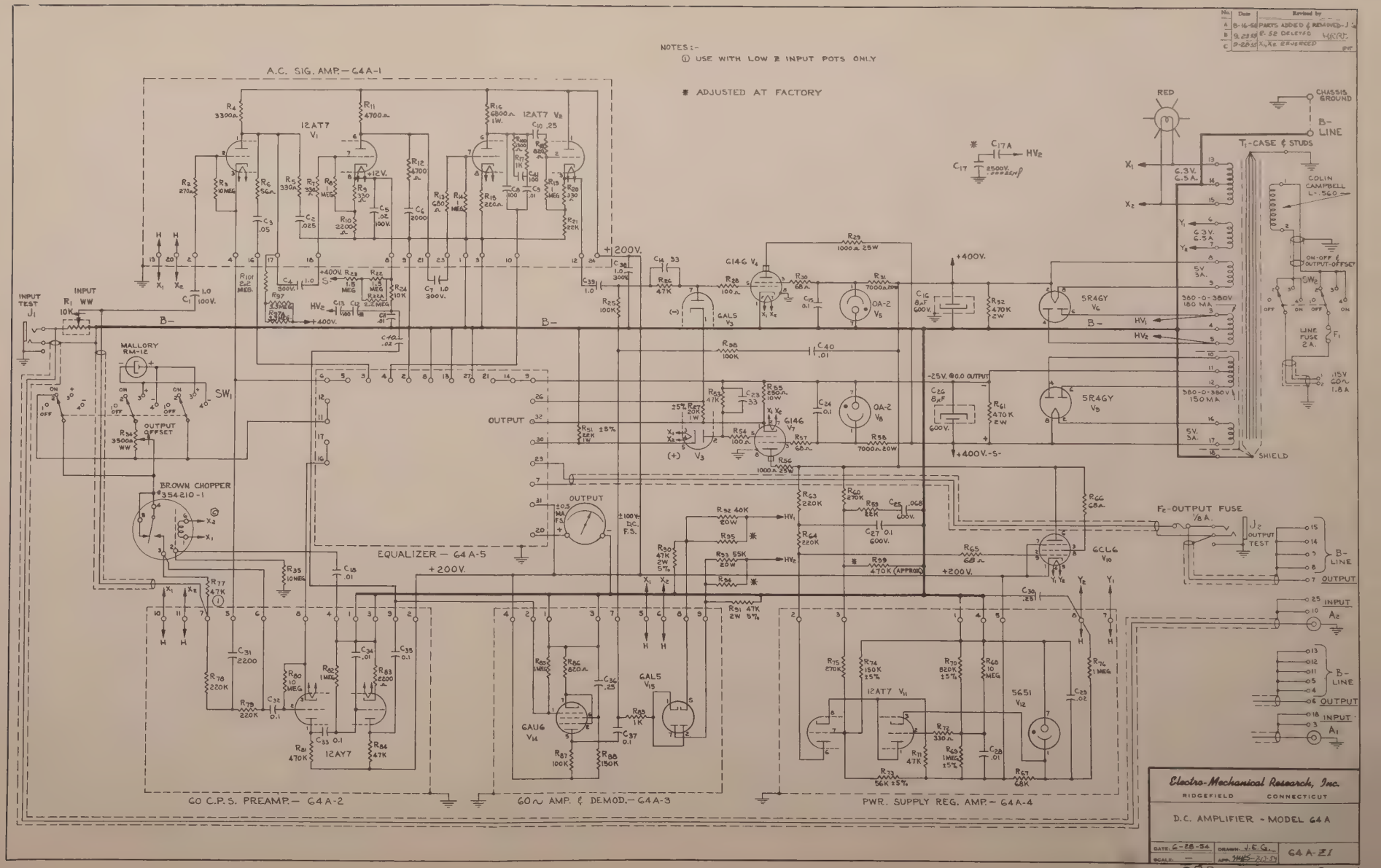

No.	Date	Revised by
A	8-16-54	PARTS ADDED & REMOVED - J
B	9-23-54	R-52 DELETED WRW
C	9-28-54	X_1, X_2 REVERSED BVT

Electro-Mechanical Research, Inc.
RIDGEFIELD CONNECTICUT

D.C. AMPLIFIER - MODEL G4A

DATE: 6-28-54 | DRAWN: J.E.G. | G4A-Z1
SCALE: — | APP. [illegible] 10-53

D00246

No.	Date	Revised by
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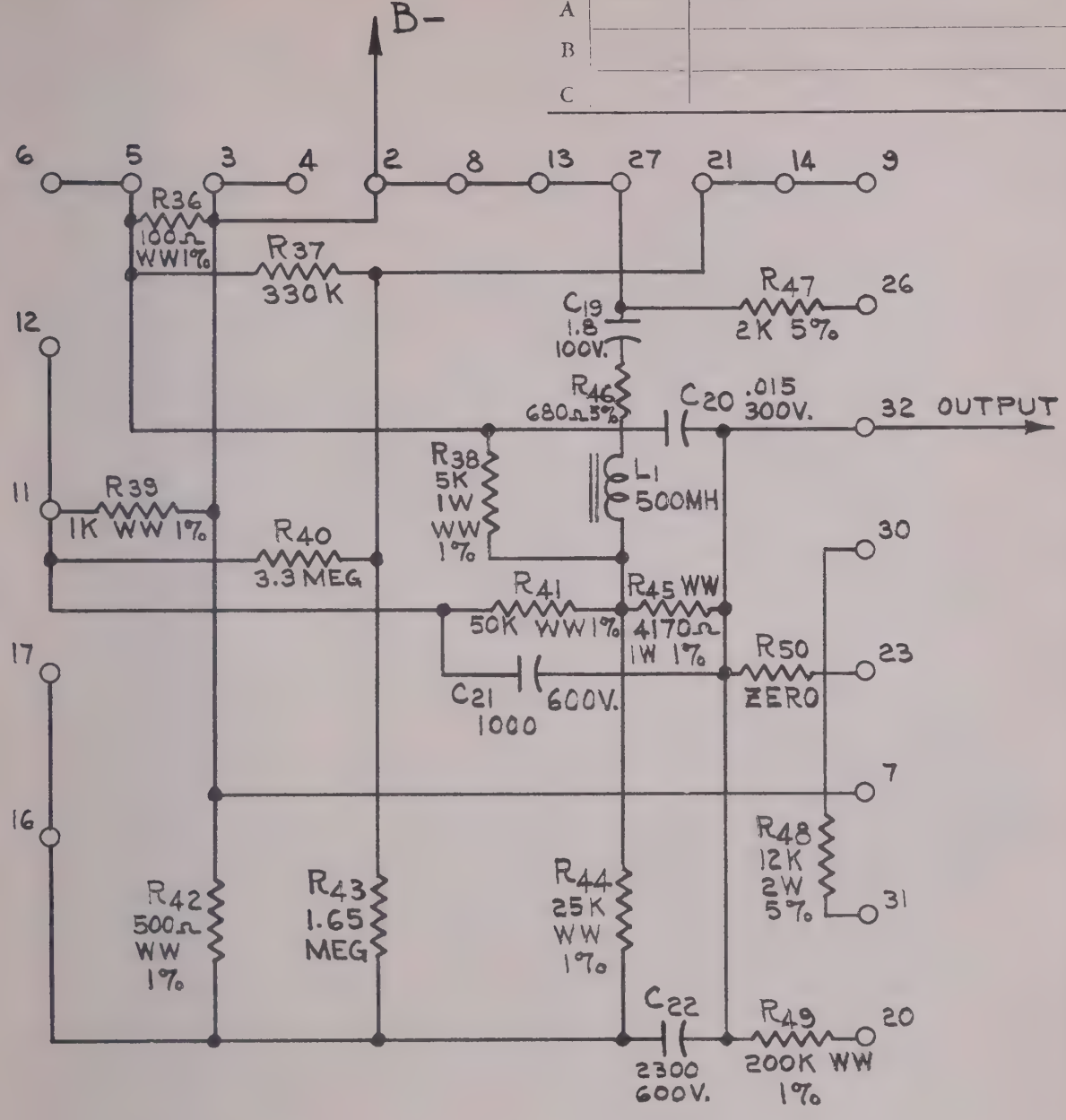
B		
C		



Electro-Mechanical Research, Inc.

RIDGEFIELD CONNECTICUT

EQUALIZER

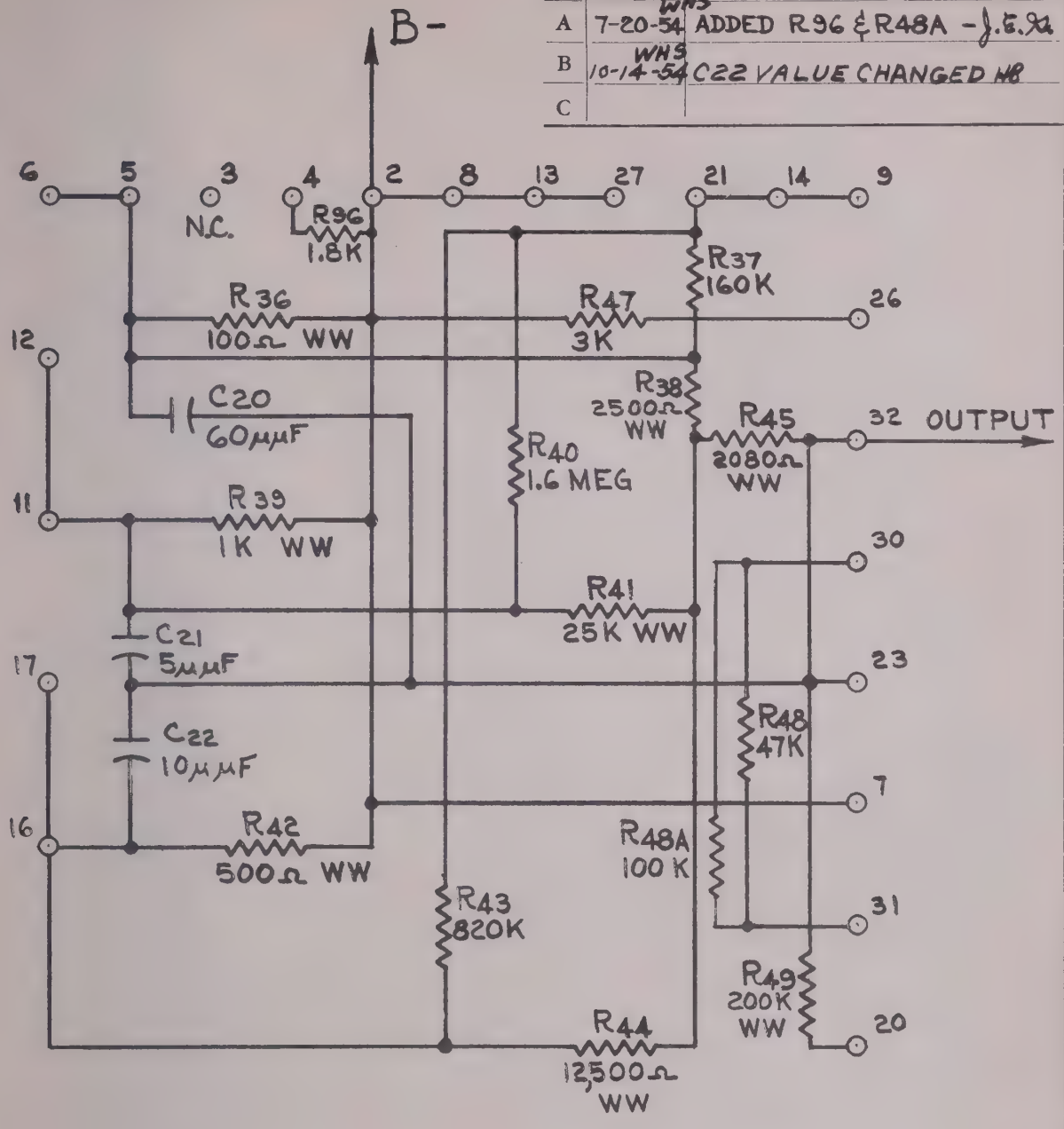
COMPENSATED - SANBORN

GAIN = x 100

DATE: 7-1-54	DRAWN: J.E.G.	64A-5A
SCALE: —	APP: 7-13-54	

A-00212

No.	Date	Revised by
A	7-20-54 WHS	ADDED R96 & R48A - J.E.G.
B	10-14-54 WHS	C22 VALUE CHANGED MB
C		



Electro-Mechanical Research, Inc.

RIDGEFIELD CONNECTICUT

EQUALIZER

D.C. - 10 KC

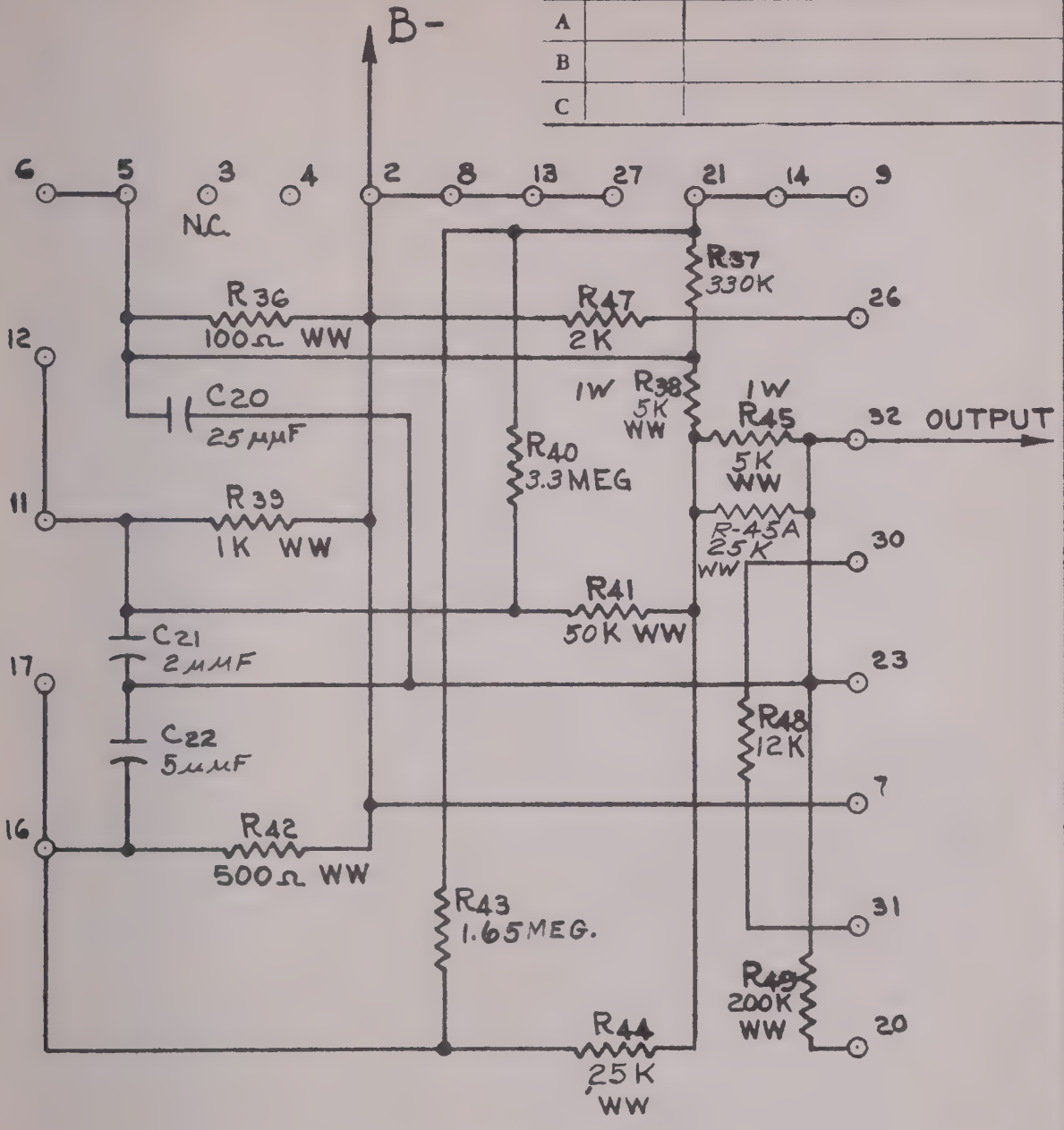
GAIN = x 50

DATE: 6-30-54	DRAWN: J.E.G.	64A-5B
SCALE: —	APP: 7-13-54	

(A) (B)

A-00231

No.	Date	Revised by
A		
B		
C		



Electro-Mechanical Research, Inc.

RIDGEFIELD CONNECTICUT

EQUALIZER

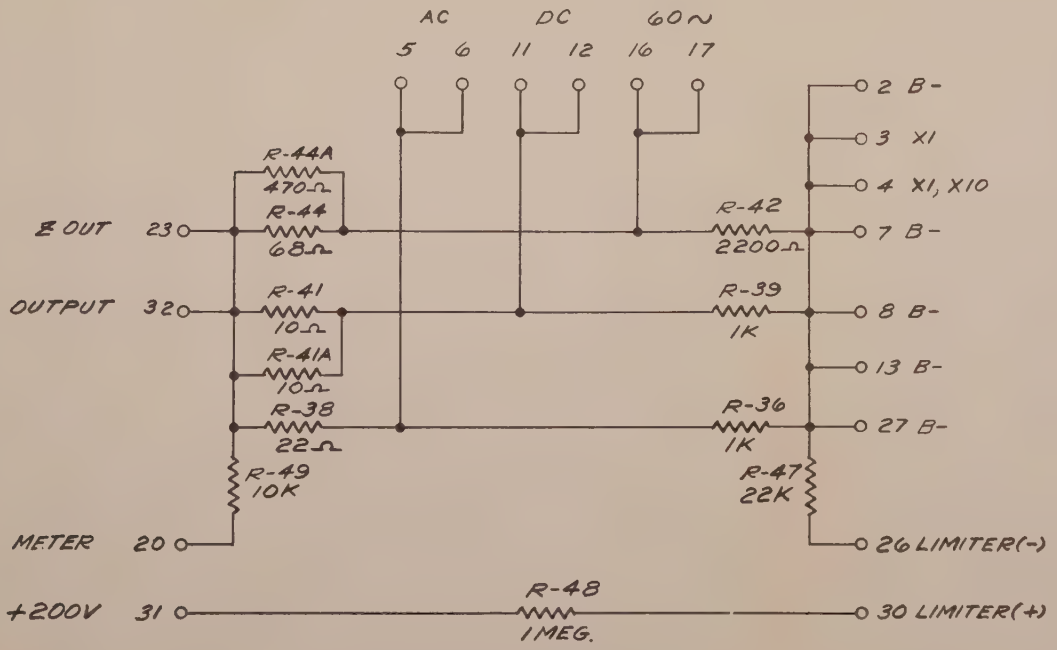
D.C. - 10 KC

GAIN = x 100

DATE: 10-14-54	DRAWN: J.E.G.	64A-5C
SCALE: —	APP: [illegible] 7-13-54	

WHS 10-15-54

A-00213



Gain = 1.0 Times; Flat ∅ C; ≧ 10 KC

Output = ± 5v or ± 100 ma to 50Ω approx. load (3.5v RMS)

$Z_{out} \cong$ 1/2 ohm + fuse resistance

Meter = ± 5v F.S.

Limit ≅ ± 7.5v ≅ ± 150 ma

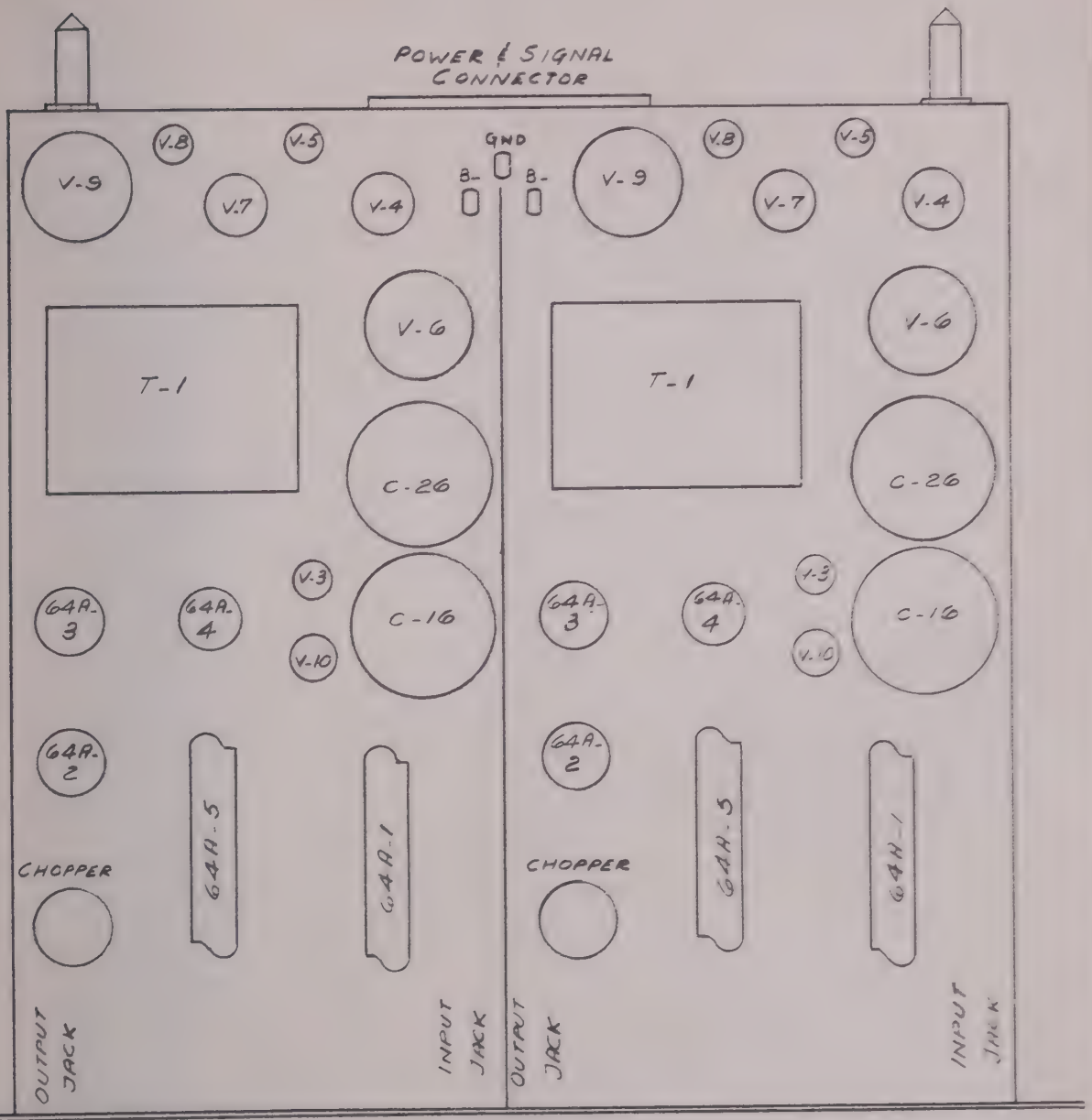
Unity Gain @ 50Ω RL with fuse F_2 shorted.

DO NOT SCALE DRAWING ALL FRACTIONAL HOLES +1/64—0

J		E		DATE 4-4-56	ELECTRO-MECHANICAL RESEARCH INC. RIDGEFIELD, CONNECTICUT
I		D		SCALE ~	
H		C		DRAWN HB	MAT'L. — TOL. UNLESS NOTED FRACTIONAL ± 1/64
G		B		CKD. HR	FINISH — DECIMAL ± .005
F		A		APP. [illegible]	EQUALIZER-FLAT-GAIN=1.0
REVISIONS				NO. REQ'D.	B-02414

64A-5D

BOTTOM VIEW



RIGHT AMPLIFIER — FRONT PANEL — LEFT AMPLIFIER

DO NOT SCALE DRAWING

J		E		DATE 6.16.55	ELECTRO-MECHANICAL RESEARCH INC. RIDGEFIELD, CONNECTICUT
I		D		SCALE	
H		C		DRAWN HRPJ.	MAT'L. / TOL. UNLESS NOTED
G		B		CKD.	FINISH / FRACTIONAL ± 1/64
F		A		APP. 7.12.55	DEC'MAL ± 005
REVISIONS				NO. REQ'D.	LAYOUT DIAGRAM 64AA DC AMPLIFIER. BOTTOM VIEW
					64AA-82

A-00211

64A AMPLIFIER—TABLE I

TEST POINT VOLTAGE CHART

D-C Volts at Socket Lugs Referred to B- Grounded

Pin Nos. Socket Nos.

	46A-1	46A-2	46A-3	46A-4	46A-5	V-3	V-4	V-5	V-6	V-7	V-8	V-9	V-10
1	0.0	0.0	0.0	0.0	NC	125	0.0	150	NC	0.04	135	NC	200
2	0.04	200	0.0	185	0	-17	HTR.	0.0	400	HTR.	-18	400	185
3	0.0	0.0	0.0	242	0.0	HTR.	150	NC	NC	135	NC	NC	400
4	0.75	0.0	200	0.0	0.05	HTR.	NC	0.0	0.0	NC	-18	0.0	HTR.
5	NC	0.75	HTR.	200	0.75	125	-26	150	NC	-17	135	NC	HTR.
6	NC	0.0	HTR.	NC	0.75	NC	0.0	NC	0.0	0.04	NC	0.0	400
7	NC	0.0	-26	HTR.	0.0	-26	HTR.	0.0	NC	HTR.	-18	NC	200
8	13	0.06	80	HTR.	0.0	---	0.0	---	400	0.0	---	400	400
9	0.0	0.0	-100	---	-18	---	---	---	---	---	---	185	---
10	0.04	HTR.	---	---	NC	---	---	---	---	---	---	---	---
11	NC	HTR.	---	---	0.0	---	---	---	---	---	---	---	---
12	67	---	---	---	0.0	---	---	---	---	---	---	---	---
14	NC	---	---	---	-18	---	---	---	---	---	---	---	---
16	0.0	---	---	---	0.06	---	---	---	---	---	---	---	---
17	167	---	---	---	0.06	---	---	---	---	---	---	---	---
18	8	---	---	---	NC	---	---	---	---	---	---	---	---
21	172	---	---	---	-18	---	---	---	---	---	---	---	---
24	200	---	---	---	NC	---	---	---	---	---	---	---	---
26	---	---	---	---	125	---	---	---	---	---	---	---	---
30	---	---	---	---	125	---	---	---	---	---	---	---	---
31	---	---	---	---	200	---	---	---	---	---	---	---	---

All other pin voltages are 0.0 D.C. volts or A-C heater voltages.
Voltages should be measured with vacuum tube voltmeter.

115 V AC Line, Zero Input 46A-5 = X100 Flat, and Output load = 3K.

64A AMPLIFIER — TABLE IA

TEST POINT VOLTAGE CHART

A-C VOLTS AT SELECTED POINTS

(1) Measured with Vacuum Tube Meter.

Across C-15	0.740 Volts RMS
Across C-24	0.420 Volts RMS

(2) Measured With Simpson Model 260

T-1	Pin 3-4	- 390 VAC
T-1	Pin 5-4	- 390 VAC
T-1	Pin 10-11	- 390 VAC
T-1	Pin 12-11	- 390 VAC

WAVE FORMS TAKEN AT SELECTED POINTS WITH DuMONT OSCILLOSCOPE MODEL 304A

Socket 64A-1
Pin No. 12 to Chassis (B-)

Socket 64A-3
Pin No. 7 to Chassis (B)

64A AMPLIFIER — TABLE II
ELECTRICAL PARTS LIST — CONDENSERS

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE &	TOLERANCE	
C-1	1.0 mfd.	Pyramid	EPGX	10%	100v
C-2	.027 mfd.	Pyramid	PGX	10%	400v
C-3	.05 mfd.	Pyramid	PGX	10%	300v
C-4	1.0 mfd.	Pyramid	PGX	10%	300v
C-5	.022 mfd.	Pyramid	PGX	10%	100v
C-6	2200 mmf.	Pyramid	PGX	10%	600v
C-7	1.0 mfd.	Pyramid	PGX	10%	300v
C-8	100 mmf.	El Menco	CM-15	E101J	
C-9	.01 mfd.	Pyramid	PGX	10%	400v
C-10	.25 mfd.	Pyramid	PGX	10%	300v
C-11	.01 mfd.	Pyramid	PGX	10%	400v
C-12	100 mmf.	El Menco	CM-15	E101J	
C-13	100 mmf.	El Menco	CM-15	E101J	
C-14	33 mmf.	El Menco	CM-15	E330J	
C-15	.1 mfd.	Pyramid	PGX	10%	300v
C-16	8 mfd.	Industrial Condenser	6GA800		600v
C-17	.0025	Sangamo	Type H		2500v
C-18	.01 mfd.	Pyramid	EPGX	10%	400v
C-23	33 mmf.	El Menco	CM-15	E330J	
C-24	.1 mfd.	Pyramid	PGX	10%	300v
C-25	.068 mfd.	Pyramid	PGX	10%	600v
C-26	8 mfd.	Industrial Condenser	6GA800		600v
C-27	.1 mfd.	Pyramid	PGX	10%	600v
C-28	.01 mfd.	Pyramid	PGX	10%	400v
C-29	.022 mfd.	Pyramid	PGX	10%	300v
C-30	.25 mfd.	Pyramid	PGX	10%	300v
C-31	.022 mfd.	Pyramid	EPGX	10%	600v
C-32	0.1 mfd.	Pyramid	EPGX	10%	100v
C-33	.1 mfd.	Pyramid	PGX	10%	300v
C-34	.01 mfd.	Pyramid	PGX	10%	400v
C-35	.1 mfd.	Pyramid	PGX	10%	300v
C-36	.25 mfd.	Pyramid	PGX	10%	300v
C-37	.1 mfd.	Pyramid	PGX	10%	300v
C-38	1.0 mfd.	Pyramid	PGX	10%	300v
C-39	.02 mfd.	Pyramid	PGX	10%	100vdc
C-40	.01 mfd.	Pyramid	EPGX		600v
C-41	100 mmf.	El Menco	CM-20		
C-42	1.0 mfd.	Pyramid	PGX	10%	300v

64A AMPLIFIER — TABLE II

ELECTRICAL PARTS LIST — RESISTORS

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
R-1	10 K	Chicago Telephone	252 1/2'' shaft, 1/2'' bushing
R-2	270 ohms	Allen-Bradley	EB-1/2 ±10%
R-3	10 meg.	Allen-Bradley	EB-1/2 ±10%
R-4	3300 ohms	Allen-Bradley	EB-1/2 ±10%
R-5	330 ohms	Allen-Bradley	EB-1/2 ±10%
R-6	56 ohms	Allen-Bradley	EB-1/2 ±10%
R-7	330 ohms	Allen-Bradley	EB-1/2 ±10%
R-8	1 meg.	Allen-Bradley	EB-1/2 ±10%
R-9	330 ohms	Allen-Bradley	EB-1/2 ±10%
R-10	2200 ohms	Allen-Bradley	EB-1/2 ±10%
R-11	4700 ohms	Allen-Bradley	EB-1/2 ±10%
R-12	4700 ohms	Allen-Bradley	EB-1/2 ±10%
R-13	680 ohms	Allen-Bradley	EB-1/2 ±10%
R-14	1 meg.	Allen-Bradley	EB-1/2 ±10%
R-15	220 ohms	Allen-Bradley	EB-1/2 ±10%
R-16	6800 ohms	Allen-Bradley	E-B-1 ±10%
R-17	1 K	Allen-Bradley	EB-1/2 ±10%
R-18	820 ohms	Allen-Bradley	EB-1/2 ±10%
R-19	1 meg.	Allen-Bradley	EB-1/2 ±10%
R-20	330 ohms	Allen-Bradley	EB-1/2 ±10%
R-21	22 K	Allen-Bradley	EB-1/2 ±10%
R-22	1.5 meg.	Allen-Bradley	EB-1/2 ±10%
R-22A	2.2 meg.	Allen-Bradley	EB-1/2 ±10%
R-23	1.5 meg.	Allen-Bradley	EB-1/2 ±10%
R-24	10 K	Allen-Bradley	EB-1/2 ±10%
R-25	100 K	Allen-Bradley	EB-1/2 ±10%
R-26	47 K	Allen-Bradley	EB-1/2 ±10%
R-27	20 K	Allen-Bradley	E-B-1 ± 5%
R-28	100 ohms	Allen-Bradley	EB-1/2 ±10%
R-29	1000 ohms	Ohmite Mfg. Co.	BLUH1 10% 20W
R-30	68 K	Allen-Bradley	EB-1/2 ±10%
R-31	7000 ohms	Ohmite	BLUME 10% 10W
R-32	470 K	Allen-Bradley	E-B-2 ±10%
R-34	3500 ohms	Chicago Telephone	252 1/2'' shaft, 1/2'' bushing
R-35	10 meg.	Allen-Bradley	EB-1/2 ±10%
R-51	22 K	Allen-Bradley	E-B-1 5%
R-52	470 ohms	Allen-Bradley	EB-1/2 ±10%
R-53	47 K	Allen-Bradley	EB-1/2 ±10%
R-54	100 ohms	Allen-Bradley	EB-1/2 ±10%
R-55	250 ohms	Ohmite	BLUME 10% 10W
R-56	1000 ohms	Ohmite	BLUH1 10% 20W
R-57	68 ohms	Allen-Bradley	EB-1/2 ±10%
R-58	7000 ohms	Ohmite	BLUH1 10% 20W
R-59	22 K	Allen-Bradley	EB-1/2 ±10%
R-60	270 K	Allen-Bradley	EB-1/2 ±10%

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE	
R-61	470 K	Allen-Bradley	EB-2 10%	
R-63	220 K	Allen-Bradley	EB-1/2 ±10%	
R-64	220 K	Allen-Bradley	EB-1/2 ±10%	
R-65	470 ohms	Allen-Bradley	EB-1/2 ±10%	
R-66	68 ohms	Allen-Bradley	EB-1/2 ±10%	
R-67	68 K	Allen-Bradley	EB-1/2 ±10%	
R-68	10 meg.	Allen-Bradley	EB-1/2 ±10%	
R-69	1 meg.	Allen-Bradley	EB-1/2 ± 5%	
R-70	820 K	Allen-Bradley	EB-1/2 ± 5%	
R-71	47 K	Allen-Bradley	EB-1/2 ±10%	
R-72	330 ohms	Allen-Bradley	EB-1/2 ±10%	
R-73	56 K	Allen-Bradley	EB-1/2 ± 5%	
R-74	150 K	Allen-Bradley	EB-1/2 ± 5%	
R-75	270 K	Allen-Bradley	EB-1/2 ±10%	
R-76	1 meg.	Allen-Bradley	EB-1/2 ±10%	
R-77	47 K	Allen-Bradley	EB-1/2 ±10%	
R-78	220 K	Allen-Bradley	EB-1/2 ±10%	
R-79	220 K	Allen-Bradley	EB-1/2 ±10%	
R-80	10 meg.	Allen-Bradley	EB-1/2 ±10%	
R-81	470 K	Allen-Bradley	EB-1/2 ±10%	
R-82	1 meg.	Allen-Bradley	EB-1/2 ±10%	
R-83	2200 ohms	Allen-Bradley	EB-1/2 ±10%	
R-84	47 K	Allen-Bradley	EB-1/2 ±10%	
R-85	1 meg.	Allen-Bradley	EB-1/2 ±10%	
R-86	820 ohms	Allen-Bradley	EB-1/2 ±10%	
R-87	100 K	Allen-Bradley	EB-1/2 ±10%	
R-88	150 K	Allen-Bradley	EB-1/2 ±10%	
R-89	1 K	Allen-Bradley	EB-1/2 ±10%	
R-90	47 K	Allen-Bradley	E-B-2 5%	
R-91	47 K	Allen-Bradley	E-B-2 5%	
R-92	40 K	Ohmite	BLUH1 10%	20 W
R-93	55 K	Ohmite	BLUH1 10%	20 W
R-94	selected by test	Allen-Bradley	EB-1/2 ±10%	
R-95	selected by test	Allen-Bradley	EB-1/2 ±10%	
R-97	3.3 meg.	Allen-Bradley	EB-1/2 ±10%	
R-97A	3.3 meg.	Allen-Bradley	EB-1/2 ±10%	
R-98	100 K	Allen-Bradley	EB-1/2 ±10%	
R-99	470 K	Allen-Bradley	EB-1/2 ±10%	
R-100	1800 ohms	Allen-Bradley	EB-1/2 ±10%	

64A AMPLIFIER — TABLE II

ELECTRICAL PARTS LIST — TUBES

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
V-1	12AT7	G.E.	12AT7
V-2	12AT7	G.E.	12AT7
V-3	GAL5	G.E. or R.C.A.	GAL5
V-4	6146	G.E. or R.C.A.	6146
V-5	0A2	G.E. or R.C.A.	0A2
V-6	5R4GY	G.E. or R.C.A.	5R4GY
V-7	6146	G.E. or R.C.A.	6146
V-8	0A2	G.E. or R.C.A.	0A2
V-9	5R4GY	G.E. or R.C.A.	5R4GY
V-10	6CL6	R.C.A.	6CL6
V-11	12AT7	G.E.	12AT7
V-12	5651	R.C.A.	5651
V-13	12AY7	G.E.	12AY7
V-14	6AU6	G.E. or R.C.A.	6AU6
V-15	GAL5	G.E. or R.C.A.	GAL5

64A AMPLIFIER — TABLE II

ELECTRICAL PARTS LIST — MISCELLANEOUS

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
F-1	313-3AG, 2A	Littelfuse	313-3AG, 2A 125 V
F-2	1/8 A.	Littelfuse	3 AG 125 V
J-1	13B	Mallory	13B
J-2	13B	Mallory	13B
P-1	DPD-32C2-34P-1L	Cannon	DPD-32C2-34P-1L
SW-1	PA-2007-SA-5-025-019	Centralab	PA-2007-SA-5-025-019
XV-3	Socket	Cinch	9355
XV-4	Socket	Cinch	51B 16220 (No. 4 Can)
XV-5	Socket	Cinch	9355
XV-7	Socket	Cinch	51B 16220 (No. 4 Can)
XV-8	Socket	Cinch	9355
XF-1	342001	Littelfuse	342001
XF-2	342001	Littelfuse	342001
	No. 1 Can	Amphenol	26-140-24
	No. 2 Can	Amphenol	77M1P11
	No. 3 Can	Amphenol	77M1-P-9
	No. 5 Can	Amphenol	26-190-32
	49RSS6	Amphenol	49RSS6
	Shield	Cinch	7S3
	Shield	Cinch	7S2
	Shield	Cinch	7S4
	Shield	Cinch	9S2
	Shield	Cinch	9S3
	Tube Cap	Millen	36002
XV-10	Socket	Cinch	53F13381
	24 Pin Connector	Vector	F-10-2N-K1.61LGJ2
	Vector Assembly	Vector	C-10NG-JL
	Vector Assembly	Vector	C-10MMK1.61LGJ2
	Vector Assembly	Vector	C-10NMGJL
	HS-2 Marion Meter	Marion	1/2 ma 50-ohm coil
	RM-12 Mallory Battery	Mallory	RM-12
T-1	L-1560 Transformer	Colin-Campbell	L-1560
	354210-1 Brown Converter	Minneapolis Honeywell	354210-1
	Kurz-Kasch Knob	Kurz-Kasch	S-308-64-BB-40281-AHSS
	Dial	Waldon Electronics	Direct drive dial
	10050 Millen	Millen	10050
	Pilot Light	Dialight Corp.	81410-111 with 6.3 v bulb
	Binding Posts	Eby	Type 38
	Shield	Cinch	7S3

64A-5A EQUALIZER—TABLE III
ELECTRICAL PARTS LIST

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
	Vector Assembly	Vector	F-12-K1.62-L
L-1	Hycor	Hycor	500 MH
C-19	1.0 mfd. Condenser	Pyramid	PGX 5% 600 v
C-19A	.8 mfd. Condenser	Pyramid	PGX 5% 200 v
C-20	.015 mfd. Condenser	Pyramid	PGX 5% 300 v
C-21	1000 mmfd. Condenser	Pyramid	PGX 5% 600 v
C-22	2200 mmfd. Condenser	Pyramid	PGX 5% 600 v
R-36	100 ohm Resistor	Mepco	WM-3 1%
R-37	330 K Resistor	Allen-Bradley	EB-1/2 watt 5%
R-38	5 K Resistor	Mepco	WM-4 1%
R-39	1 K Resistor	Mepco	WM-3 1%
R-40	3.3 meg. Resistor	Allen-Bradley	EB 5%
R-42	500 ohms Resistor	Mepco	WM-3 1%
R-43	1.65 meg. Resistor	Allen-Bradley	EB 5%
R-44	25 K Resistor	Mepco	WM-3 1%
R-45	4170 Resistor	Mepco	WM-4 1%
R-46	680 ohm Resistor	Allen-Bradley	EB 5%
R-47	2 K Resistor	Allen-Bradley	EB 5%
R-48	12 K Resistor	Allen-Bradley	EB 5% 2 watt
R-49	200 K Resistor	Mepco	WM-3 1%

64A-5A EQUALIZER — TABLE III
MECHANICAL PARTS LIST

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
	Terminal Board	Vonhet Electronics	
	Terminal Board	Vonhet Electronics	
	Machine Screws		6-32 x 2-1/2'' BH Steel Cad. Plated Machine Screws
	Machine Screws		6-32 x 3/4'' BH Steel Cad. Plated Machine Screws
	Brass Spacer		1/2'' long Tapped, 6-32
	Machine Screws		6-32 x 1/4'' Long BH Steel Cad. Plated Machine Screws
	Machine Screws		6-32 x 1-3/4'' Long BH Steel Cad. Plated Machine Screws
	Lock Washers		No. 6
	Flat Washers		No. 6
	Fiber Washers		No. 6

64A-5B EQUALIZER—TABLE IV

ELECTRICAL PARTS LIST

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
C-20	56 mmf.	El Menco	CM15E560J
C-21	5 mmf.	El Menco	CM15C050K
C-22	10 mmf.	El Menco	CM15C100J
R-36	100 ohms	Mepco	WM-3 1%
R-37	160 K	Allen-Bradley	EB 1/2 5%
R-38	2500 ohms	Mepco	WM-4 1%
R-39	1 K	Mepco	WM-3 1%
R-40	1.6 meg.	Allen-Bradley	EB-1/2 5%
R-41	25 K	Mepco	WM-3 1%
R-42	500 ohms	Mepco	WM-3 1%
R-43	820 K	Allen-Bradley	EB-1/2 5%
R-44	12.5 K	Mepco	WM-3 1%
R-45A	12.5	Mepco	WM-3 1%
R-45	2500 ohms	Mepco	WM-4 1%
R-47	3 K	Allen-Bradley	EB-1/2 5%
R-48	33 K	Allen-Bradley	EB-1 5%
R-49	200 K	Mepco	WM-3 1%
R-96	1.8 K	Allen-Bradley	EB 5%
		Vector Electronics	F-12-K1.62L Vector Assembly

64A-5B EQUALIZER—TABLE IV
MECHANICAL PARTS LIST

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
	Terminal Board		
	Machine Screws		6-32 x 2-1/2'' BH Steel Cad. Plated
	Brass Spacers		1/2'' long, Tapped, 6-32
	Machine Screws		6-32 x 1/4'' BH Steel Cad. Plated
	Machine Screws		6-32 x 1-3/4'' BH Steel Cad. Plated
	Washers		No. 6
	Flat Washers		No. 6
	Fiber Washers		No. 6

64A-5C EQUALIZER—TABLE V
ELECTRICAL PARTS LIST

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE		
C-20	25 mmf.	El Menco	CM-15		
C-21	2 mmf.	El Menco	CM-15		
C-22	5 mmf.	El Menco	CM-15		
R-36	100 ohms	Mepco	WM-3	1%	
R-37	330 K	Allen-Bradley	EB-1/2	5%	1/2 W
R-38	5000 ohms	Mepco	WM-4	1%	
R-39	1 K	Mepco	WM-3	1%	
R-40	3.3 meg.	Allen-Bradley	EB-1/2	5%	1/2 W
R-41	50,000 ohms	Mepco	WM-3	1%	
R-42	500 ohms	Mepco	WM-3	1%	
R-43	1.6 meg.	Allen-Bradley	EB-1/2	5%	1/2 W
R-44	2500 ohms	Mepco	WM-3	1%	
R-45A	2500 ohms	Mepco	WM-3	1%	
R-45	2500 ohms	Mepco	WM-3	1%	
R-47	2 K	Allen-Bradley	EB-1/2	5%	1/2 W
R-48	12 K	Allen-Bradley	EB-2	5%	2 W
R-49	200 K	Mepco	WM-3	1%	
R-96	1.8 K	Allen-Bradley	EB	5%	
		Vector Electronics*	F-12-K1.62L Vector Ass'y		

*Note: CANS MUST BE FASTENED TO BASES WITH "J" NUTS AND SIDE SCREWS INSTEAD OF LONG CORNER SCREWS. (6-32 J NUTS, 6-32 x 1/4" SIDE SCREWS)

64A-5C EQUALIZER—TABLE V
MECHANICAL PARTS LIST

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
	Terminal Board	Vonhet Electronics	Terminal Board
	Terminal Board	Vonhet Electronics	Terminal Board
	Machine Screws		6-32 x 2-1/2'' BH Steel Cad. Plated Machine Screws
	Machine Screws		6-32 x 1-3/4'' BH Steel Cad. Plated Machine Screws
	Brass Spacers		1/2'' long, tapped, 6-32
	Machine Screws		6-32 x 1/4'' BH Steel Cad. Plated Machine Screws
	Lock Washer		No. 6
	Flat Washer		No. 6
	Fiber Washer		No. 6

64A-5D EQUALIZER—TABLE VI
ELECTRICAL PARTS LIST

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
R-36	1000 ohms	Electra	1/2 w 1%
R-38	22 ohms	Electra	1/2 w 1%
R-39	1000 ohms	Electra	1 w 1%
R-41	10 ohms	Electra	1 w 1%
R-41A	10 ohms	Electra	1 w 1%
R-42	2200 ohms	Electra	1/2 w 1%
R-44	68 ohms	Electra	1/2 w 1%
R-44A	470 ohms	Electra	1/2 w 1%
R-47	22000 ohms	Electra	1/2 w 1%
R-48	1 Meg.	Electra	1/2 w 1%
R-49	10 K	Electra	1/2 w 1%
Vector*	62-L Vector Assembly		F-12, K1

64A-5D EQUALIZER—TABLE VI
MECHANICAL PARTS LIST

SYMBOL	DESCRIPTION	MANUFACTURER	TYPE & TOLERANCE
Dwg. B-00140	Terminal Board, Top	Von's Speciality	
Dwg. B-00140	Terminal Board, Bottom	Von's Speciality	
	Brass Spacer		1'' Long Clearance, 6-32
	Brass Spacer		1/2'' Long, Tapped, 6-32
	Machine Screws		6-32 x 1/4'' F.H. Cad. Plated Steel
	Machine Screws		6-32 x 3/4'' BH Cad. Plated Steel
	Lock Washer (Ring)		No. 6 Cad. Plated Steel
	Flat Washer		No. 6 Cad. Plated Steel